UNIT 10

ECOLOGICAL PRINCIPLES

10 Ecological Principles

Introduction

Ecology is the study of the environment and it enables us to comprehend how creatures coexist in distinct physical situations. In order to investigate the environment, scientists pose questions, such as 'how do organisms interact with the surrounding living and non-living factors?' 'What do creatures require in their existing habitats to survive and thrive?' Ecologists must study and observe all types of life and their ecosystems around the globe to answer these issues.

In addition to studying how ecosystems operate, ecologists also investigate what occurs when ecosystems do not operate correctly. Changes in ecosystems can be caused by a variety of factors, including diseases among the local creatures, temperature increases, and increased human activities. Understanding these changes can assist ecologists in anticipating future ecological issues and in informing other scientists and policymakers about the threats to local ecosystems.

Divisions of Ecology

The two principal ecological branches are autecology and synecology.

Autecology

Autecology is the study of the relationship between an individual animal or plant's life span and abiotic conditions. This covers the study of the individual species' life history, growth, reproduction, nutrition, population dynamics, behaviour, and development.

Synecology

Synecology is the study of communities or complete ecologies. In this subject, ecologists specialise in defining the interaction and total energy and nutrient movement within an ecosystem. A scientist in this field may examine a whole desert or marine ecosystem.

Organisational Levels in Ecology

Organisms

An organism is an independently functioning living creature. Some of the examples include plants, animals, bacteria, protist, fungi, etc.

Organism ecologists investigate adaptations, which are advantageous characteristics that arise from natural selection and allow organisms to inhabit a certain area. These can be morphological, physiological, or behavioural.

Population

A population is a group of individuals of the same species living in one shared community. These groupings of organisms share similar traits that allow them to benefit mutually.

A population ecologist investigates the size, shape, structure, and density of this species, as well as, the environmental changes that occur throughout time.

Community

In ecology, a community is the population of diverse creatures living in the same environment or region. Community ecologists examine the interrelationships between populations and their effects on the local community.

Ecosystem

An ecosystem is a community of creatures and their interactions with their physical environment. Environment ecologists examine the recycling of nutrients and the transmission of energy from one organism to another within the same ecosystem.

Environment

Environment consists of the physical and chemical surroundings, in which living creatures interact. This environment determines the creation, behavioural features, and population of these species.

Biome

The properties of climate, location, species, adaptations, and features are used to describe a biome, which is a huge geographic region including plants and animals.

A biome ecologist is concerned with the distribution of organisms throughout the world's continents.

Chaparral Biome

The chaparral biome spans minor areas of the US west coast, Cape Town, Australia's western tip, the Mediterranean coast, and the west coast of South America.

Chaparral biomes encompass around two per cent of the planet's surface and consist of a variety of topography, including rocky hills, mountain slopes, and flat plains. The climate of a chaparral biome is comparable to that of the Mediterranean, with hot and dry summers.

Desert Biome

The desert biome is characterised by severe heat and aridity. This biome encompasses approximately one–fifth of the Earth and is subdivided into four groups, namely hot and dry, semiarid or steppe, coastal, and cold desert biomes.

Aquatic Biome

The aquatic biome is the largest of the world's biomes. It covers around 70 per cent of the planet's surface and consists of both fresh and salt water.

The marine biome comprises the most diversified plant and animal species.

Tundra Biome

There are fewer plant species in the tundra than in any other biome; in Finnish, tundra refers to a barren or treeless terrain. Tundra is located between 550 and 700 degrees north latitude and covers around 20 per cent of the Earth's surface. The tundra biome is located north of the taiga and encompasses the far northern regions of Alaska, Canada, and Russia, as well as, the entire Greenland.

Biosphere

The biosphere refers to the land and bodies of water where life exists on Earth. A specialist in this discipline is concerned with the global distribution pattern of species. In addition, they investigate how species interact, how climate influences species, and how natural occurrences drive species' ranges.

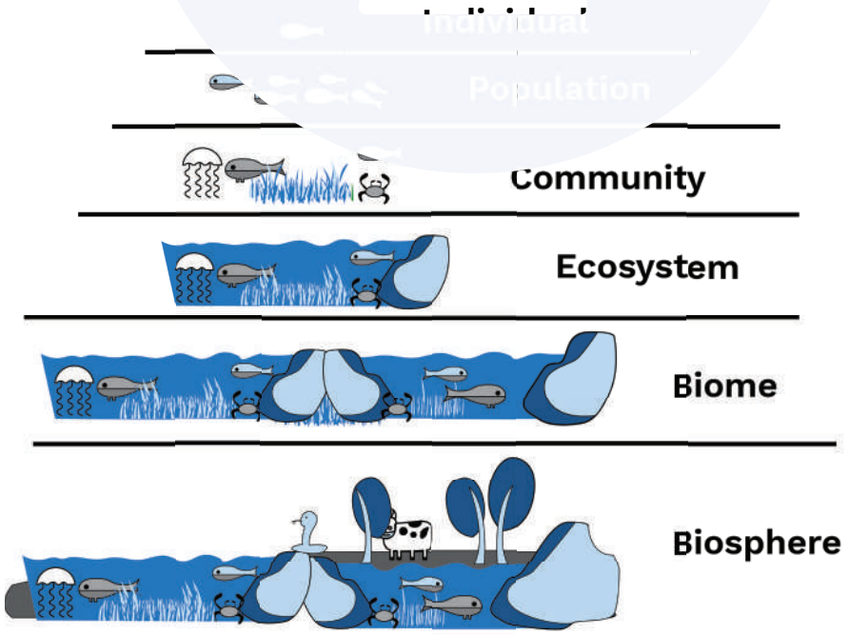

Fig. 10.1 Levels of Organisation

Environment

Anything that affects the health of living beings is considered an environmental component. Abiotic influences include the surrounding temperature, the amount of sunlight, and the pH of the water and soil in which an organism resides. The availability of food organisms and the presence of biological specificity, competitors, predators, and parasites are examples of biotic factors.

The soil is the uppermost layer of the Earth's crust and is primarily made of organic materials and rock particles that sustain life. A soil profile is a vertical cross-section of the soil consisting of layers that run parallel to the surface. These soil layers are called horizons.

During its formation, the soil is structured in horizons or layers. The soil profile refers to these layers or horizons. The vertical portion of soil is exposed by a soil pit. The colour and size of the soil particles make it simple to identify the layers of soil. Topsoil, subsoil, and parent rock are the various soil layers. Each soil layer possesses unique qualities.

The soil profile can also be used to determine the soil's function. It helps in distinguishing the given soil sample from other samples based on its colour, texture, structure, thickness, and chemical composition.

Soil Deposits

The soil profile consists of a sequence of horizons or layers of soil layered one on top of the other. The letters O, A, E, C, B, and R correspond to these strata or horizons.

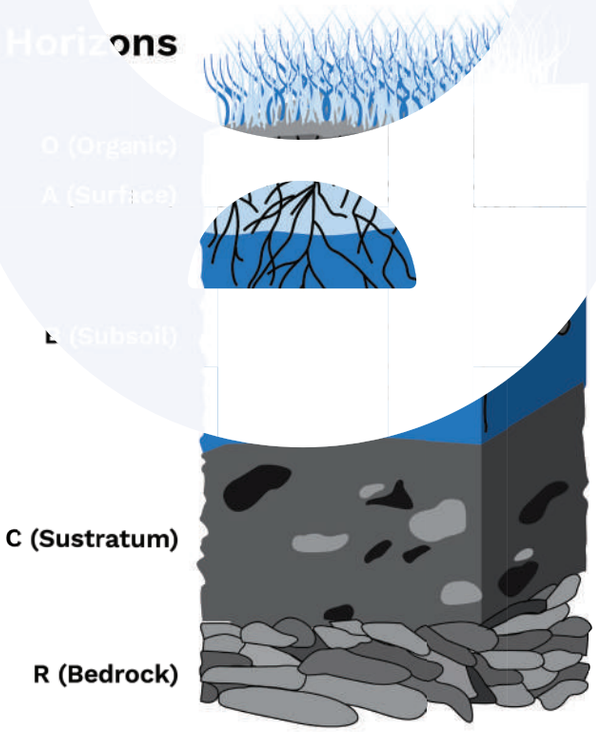

Fig. 10.2 Soil Profile

The O-Hilltop

The O horizon is the uppermost layer of the topsoil, which is formed primarily of organic elements, such as dried leaves, grasses, dead leaves, small boulders, twigs, surface creatures, fallen trees, and other degraded organic matter. This soil horizon is typically black brown or dark brown in colour, mostly due to the presence of organic material.

The A Horizon or Surface Dirt

Known as the humus layer, this stratum is rich in organic material. This stratum contains both organic material and other degraded substances. The topsoil is soft and permeable, so it can hold sufficient air and water.
In this layer, seed germination and the production of new roots occur, resulting in the growth of a plant. This layer contains microorganisms, such as Earthworms, fungi, and bacteria.

The E Agenda

This layer consists of nutrients that have been leached from the O and A horizons. This layer is more prevalent in forested regions and has a lower clay per centage.

The Subsoil or B Horizon

Just beneath the topsoil and above the bedrock lies the subsurface horizon. It is relatively more rigid and compact than topsoil. It has lower levels of humus, soluble minerals, and organic matter. It is a place of mineral and metal salt deposition, including iron oxide.
This layer contains more water than the topsoil and is a lighter shade of brown due to the presence of clay soil. When ploughing the fields, the soil of horizons A and B is frequently combined.

C Horizontal or Saprolite

This layer is devoid of biological material and consists of shattered bedrock. Saprolite is another name for this stratum. This region's geological composition is cement-like.

Horizontal R

It consists of a compacted and bonded layer. Here, you can find a variety of rock kinds, including granite, basalt, and limestone.

What Is Soil Water Content?

Soil moisture refers to the amount of water present in the soil. Various factors impact the soil's absorption of water. It is essential to the development of soil. Water comes to the surface as a result of precipitation. The particle size distribution of soil controls its porosity and causes the vertical downward movement of water, known as infiltration. This permeation penetrates down into the soil layers until saturation is reached.
Upon hitting this barrier, water cannot continue to infiltrate vertically, therefore it moves laterally. Surface ponding refers to the formation of persistent puddles as a result of saturation. Root zone moisture refers to the water available to plants, whereas surface soil moisture refers to the water available in the soil's uppermost region.

Types of Soil Humidity

The various forms of water found in the soil are as follows.

Gravitational Water

Gravitational water refers to the water that reaches the water table of the land due to the force of gravity. The plants do not have access to this.

Hygroscopic Water

This water also remains unavailable to plants. It is a thin layer of water held in place by soil particles.

Chemically Processed Water

Water is found in the chemical compositions of soil particles. This is referred to as chemically combined water. This is inaccessible to the plants as well.

Water Capillary

Water is readily absorbable by plants. Small capillaries contain water between dirt particles.

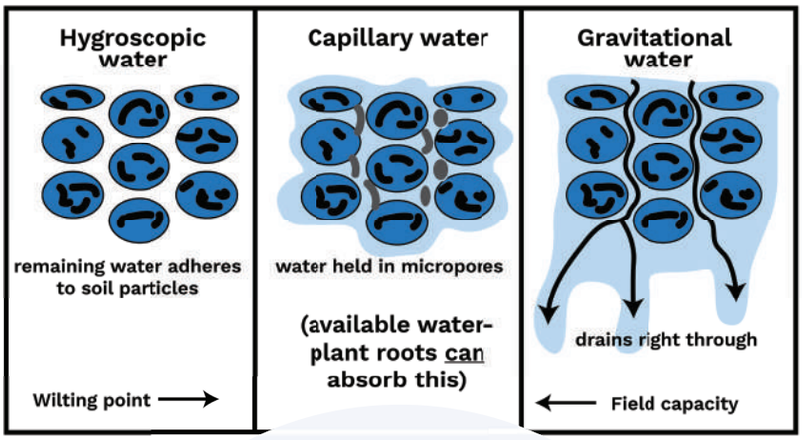

Fig. 10.3 Types of Water

Humidity of the Air

Due to the presence of hygroscopic hair and sponge-like velamen tissues, the dangling roots of the epiphytes absorb the air's moisture.

Importance of Soil Moisture Contents

- The nutrients for plant growth are carried by soil water.
- The yield of a region's crop depends on the soil moisture content.
- Soil moisture contents are important for soil temperature maintenance.
- Soil moisture acts as nutrient and is crucial for soil formation.
- Plants that require a large quantity of water thrive best on soil that is rich in moisture, e.g., paddy.
- The biological activity of soil microorganisms is stimulated by soil moisture.
- The basic requirement for photosynthesis in plants is water.

Atmosphere

There are five major and several subsidiary layers in the Earth's atmosphere.

The principal atmospheric layers, from lowest to highest, are the troposphere, stratosphere, mesosphere, thermosphere, and exosphere.

Troposphere

The troposphere stretches from Earth's surface to a height of around 12 kilometres (7.5 miles) on average, being shorter near the poles and taller at the equator. Nonetheless, this relatively thin layer is responsible for retaining all oxygen that plants and animals require for photosynthesis, as well as, 99 per cent of all water vapour and aerosols (minute solid or liquid particles suspended in the atmosphere). Since the majority of tropospheric heat is generated by the transfer of energy from Earth's surface, tropospheric temperatures normally decrease with increasing altitude. By the weight of the atmosphere above it, the troposphere is the densest layer of the atmosphere. With the exception of cumulonimbus thunder clouds, whose tops can ascend into the lowest levels of the surrounding stratosphere, the troposphere is home to the majority of the Earth's weather and practically all clouds formed by weather. This is where the majority of aviation occurs, including the transition zone between the troposphere and stratosphere.

Stratosphere

The stratosphere, which is located between approximately 12 and 50 kilometres (7.5 and 31 miles) above the Earth's surface, is arguably best known

as the location of the ozone layer, which shields us from the Sun's ultraviolet radiation. Because of this UV rays, stratospheric temperatures increase with increasing altitude. The stratosphere is nearly devoid of clouds and weather, however polar stratospheric clouds occasionally form at its lowest, coldest levels. It is also the greatest level of atmosphere that jet aircraft can reach.

Mesosphere

The mesosphere, located between approximately 50 and 80 kilometres (31 and 50 miles) above the Earth's surface, becomes progressively colder with increasing altitude. In fact, this layer's surface is the coldest place on Earth, with an average temperature of minus 85 degrees Celsius (minus 120 degrees Fahrenheit). Under specific conditions and at specific times of the day, noctilucent clouds, the highest clouds in the Earth's atmosphere, can be observed by the naked eye. Most meteors burn up in this layer of the atmosphere. Rocket-powered aircraft and sounding rockets can reach the mesosphere.

Thermosphere

The thermosphere is located between approximately 80 and 700 kilometres (50 and 440 miles) above the Earth's surface, and its lowest portion comprises the ionosphere. Due to the extremely low density of molecules in this layer, temperatures rise with increasing altitude. Both clouds and water vapour are absent. Sometimes, the aurora borealis and aurora australis can be observed here. The International Space Station has a thermosphere orbit.

Exosphere

The exosphere is the uppermost layer of the Earth's atmosphere. Located between 700 and 10,000 kilometres (440 and 6,200 miles) above the planet's surface, it mixes with the solar wind at its summit. Due to the incredibly low density of these molecules, this layer does not act like a gas, and particles escape into space. In the lowest levels of the exosphere, where there is no weather, the aurora borealis and aurora australis are sometimes visible. The majority of satellites orbit Earth in the exosphere, the farthest edge of space.

While there is no definitive line between Earth's atmosphere and outer space, most scientists use the Karman line, approximately 100 kilometres (62 miles) above the planet's surface, to identify the transition point, as 99.99997 per cent of Earth's atmosphere sits below this point. A research published in February 2019 using data from the NASA/European Space Agency Solar and Heliospheric Observatory (SOHO) spacecraft reveals, that the geocorona, a cloud of hydrogen atoms, may stretch approximately 391,000 miles (629,300 kilometres) into space, well beyond the Moon's orbit.

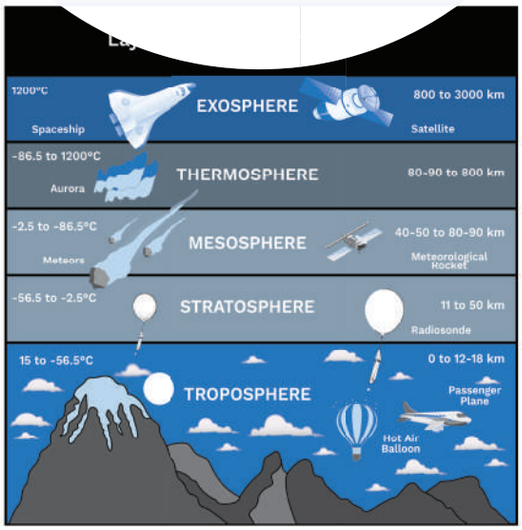

Fig. 10.4 Layers of the Atmosphere

Environmental Factors Affecting Living Beings

Following are the three ecological elements that have an effect on plants and animals. These are as follows.

1. Luminance
2. Temperature
3. Rainfall

Luminance

Illumination is an essential ecological component. The exposure of protoplasm directly to light is fatal. Nonetheless, life could not exist without light, as it is the ultimate source of energy. In addition, the evolution of the biosphere has largely resulted from the taming of incoming solar radiation, with beneficial wavelengths used and detrimental ones blocked.

Consequently, light is a form of radiation, namely the visible wavelength of electromagnetic radiation. This portion of the electromagnetic spectrum extends from violet (shorter wavelength) through red (longer wavelength). Ultraviolet light has wavelengths shorter than violet and is visible to fish and insects but invisible to humans.

Longer than red wavelengths are infrared and microwave radiation. Half of the energy of the solar radiation that reaches the Earth's surface is in the visible spectrum and the other half is in the near-infrared. The ozone layer of the atmosphere prevents all but a few ultraviolet photons from reaching the surface of the Earth. The ecologically significant characteristics of light are its quality (wavelength), intensity (energy), and duration (length of day).

Light Quality

Both plants and animals respond to different wavelengths. For instance, the rate of photosynthesis varies slightly with wavelength. Only primates among mammals have well-developed colour vision.

1. **Intensity of light:** Through its effect on primary production, the intensity of light affects the entire ecosystem. The rate of photosynthesis increases linearly up to the optimal or saturation intensity of light. Individual plants and communities can adjust to varying light intensities by becoming shade-adapted (i.e., reaching saturation at low intensities) or sun-adapted.

   Other than diatoms, phytoplankton are shade-adapted, and light intensities greatly impede photosynthesis in them (peak production in the sea occurs below rather than at the surface). In contrast, diatoms are sun-adapted and exhibit maximum photosynthesis when light intensity is less than five per cent of full sunlight.
2. **Length of daylight:** The duration of light, also known as photoperiodicity, relates to the length of the day's light and dark periods. Changes in day length gives a hint to organisms about the progression of seasons, allowing them to organise their life cycle events, breeding conditions, and other activities accordingly.

   Photoperiod may be responsible for the timing of numerous plant events, including flowering. Short-day plants demand shorter days to bloom, for example, soyabean, chrysanthemum, violet, etc. Long-day plants require longer day lengths to blossom, for example, evening primrose, spinach, wheat grass, etc.
3. **Interaction between water and light:** Water layers impact the intensity of light. With increasing depth, light intensity steadily declines. Light transmission through water is dependent on turbidity, solute concentration, water velocity, plankton growth, etc. Therefore, submerged plants receive less light than uncovered plants floating on the water's surface.

Light's Effects on Plants

Light exerts direct and indirect effects on plant life. Consequently, it fulfils the following purposes.

1. **Chlorophyll synthesis:** The formation of chlorophyll in most plants requires sunlight. Thus, light is necessary for the production of food and the survival of all life forms.
2. **Expiration:** Plants that are exposed to light increase their warmth and transpiration

rate. Consequently, water absorption is altered by the proportional effect on transpiration rates. This could lead to the creation of arid habitat.

3. **Stomatal regulation:** Light affects the rate of transpiration and absorption by regulating the opening and closing of stomata.
4. **Plant distribution:** The distribution of light intensity varies with latitude, which is likely one of the causes of the diverse vegetation in different regions of the globe. In case of a water body, phytoplankton becomes concentrated in regions, where solar radiation is the highest. It is one of the reasons why phytoplankton become concentrated near the water's surface during the day.
5. **Classification of plants:** Plants can be categorised according to their light requirements:
   a) **Heliophytes** thrive in direct sunlight.
   b) **Sciophytes** thrive in low-light conditions.

   Compared to sciophytes, heliophytes have stronger stems, more frequent branching, smaller chloroplasts, longer roots, rapid respiration rate, low water content, greater concentration of salts and sugars, and high osmotic pressure, among other characteristics.
6. **Photoperiodicity:** 'Photoperiod' is the entire length of daylight period to which plants are exposed. It has a significant role in the local distribution of plants by affecting stem elongation, blooming, and fruit development, among other things. On the basis of photoperiod, plants may be Short-day plants (Rice, soybean, onion, and Christmas cactus) or Long-day plants (Salvia, Datura, Cannabis, and Cosmos). (Examples: Brassica, Secale, and Sorghum).
7. **Photosynthetic performance:** The photosynthetic efficiency fluctuates with light intensity throughout the day. The peak efficiency is reached at 02:00 pm when the light intensity is at its highest.

Light's Effects on Animals

Light has a significant impact on the following animal activities.

1. **Metabolism:** Light influences the metabolic activities of animals by its heating effect on tissues. It increases the activity of enzymes and the degree of solubility of salts and minerals. Cave-dwelling animals have sluggish metabolic rates.
2. **Locomotion:** Some lesser animals' locomotion is influenced by light, a phenomenon known as photokinesis. The blind larvae of the mussel crab (Pinnotheres), for instance, travel quicker when exposed to higher light intensity. As the sun becomes obscured by clouds, locusts cease their flight.

   The movement of animals in reaction to light is referred to as phototaxis, and these movements are known as phototactic. As they migrate towards a light source, some creatures, such as Euglena, are considered to be positively phototactic. Others, such as Earthworms, slugs, and copepods, migrate away from the light source and are hence referred to as negatively phototactic. Some creatures, such as the polyps of many coelenterates, move only a portion of their bodies in reaction to light; this behaviour is known as phototropism.
3. **Procreation:** Some birds' gonads become active when the light intensity increases. Thus, light stimulates reproduction. Some animals (sheep, goats, etc.) are short-day animals, and they can be induced to engage in sexual behaviour by reducing their exposure to daylight. Long-day animals include starlings, turkeys, etc., whereas squirrels, guinea pigs, etc., are indifferent to the duration of light exposure.
4. **Development:** When exposed to sufficient light, the larva of salmon develops normally. Nonetheless, fast mortality occurs in the absence of light. The rate of change in the daily photoperiod initiates the smoltification process in fish. The larva of Mytilus develops better in darkness than in light.

5. **Eyes:** In cave-dwelling organisms, *Proteus anguinus*, and deep-sea fishes, the eyes are non-existent or rudimentary. This is a result of the lack of light in these settings. Some deep-sea fish have eyes that are larger than average to collect whatever light that may be there. However, these eyes are completely devoid of cones.
6. **Vision:** A majority of animals can only perceive objects and distinguish colours in the presence of light. However, when nocturnal creatures are exposed to sufficient light, their vision is impaired.
7. **Formation of calcium:** The synthesis of calcium in bones requires sunlight. In the lack of sunlight, deep-sea fishes are unable to synthesise calcium, resulting in brittle bones.
8. **Pigmentation:** The pigmentation process in animals is influenced by light. In the presence of light, colouration and mimicry are most apparent.
9. **Photoperiodicity:** Photoperiodism has a major effect on animals through processes such as gonad activity, reproduction, metamorphosis, and migration, among others. It is recognised that photoperiodism affects the migration of birds and fishes. Longer day length appears to stimulate early maturation in several catfish species.
10. **Vitamin D synthesis:** The sun's ultraviolet rays contribute to the creation of vitamin D in animals.

Temperature

Life on Earth exists within a temperature range of -200 to 100 degrees Celsius. In actuality, the majority of species' activities are constrained to an even narrower temperature range. A few microorganisms (bacteria) can tolerate and reproduce in hot springs where the temperature is near the boiling point (80°C for cyanobacteria). On land, the range of temperature variance is greater than in water. Thus, aquatic creatures have a narrower temperature tolerance range than terrestrial animals.

Therefore, temperature is a limiting issue. It influences organisms by regulating their morphological, physiological, and behavioural characteristics via heat gain, heat loss, or both. When heat gain and heat loss are equal, the animal or plant's body temperature will remain constant. If heat intake exceeds heat loss and body temperature will increase, and vice versa.

Homoiotherms and Poikilotherms

There are two type of animals based on the relationship between body and environmental temperature poikilotherms and homoiotherms.

Poikilotherms

Poikilotherms, often known as cold-blooded organisms, are those whose body temperature tends to match that of their surroundings. As the external temperature rises or falls, the rates of their bodily functions increase or decrease accordingly. Thus, poikilotherms become dormant as the temperature decreases. They have no intrinsic physiological means to maintain a steady body temperature. Poikilotherms constitute a majority of smaller creatures, especially those that live in water. These may be two species types—freeze-tolerant species (extracellular ice production is tolerated) and freeze-sensitive species (which do not survive on freezing).

However, Antarctic mites are active even at subzero temperatures, and they may seek out microhabitats (if available). Their continued life hinges on their ability to tolerate the cold. regulate their body temperature by behavioural rather than physiological causes.

Homoiotherms or Homeotherms

Homeotherms, often known as warm-blooded organisms, are able to maintain a steady body temperature regardless of environmental temperature variations. They are able to withstand low temperatures by storing enough food to keep heat production high and maintain normal body temperature. If a homoiotherm is unable to amass enough food, its body temperature will decline and it will perish rapidly if its body temperature is above the freezing point.

Homoiotherms are primarily birds and mammals with physiological processes that keep their body temperature constant regardless of changes in the temperature of their environment.

To maintain a high body temperature in cold environments, homoiotherms boost their metabolic rate or enhance their insulation by adding fat or fluffing up their feathers or fur. Warm-blooded animals, on the other hand, reduce their heat production and increase their heat loss via draining water from sweat glands, panting, etc. in response to high external temperatures in order to maintain low body temperatures.

Thus, poikilotherms are energy conserving and weak, whereas, homoiotherms are extravagant and strong. In a strong food-rich environment, homoiotherms thrive, but poikilotherms struggle. Poikilotherms are capable of shutting down when food, water, or oxygen are no longer available for the season.

Hibernation

Few animals (e.g., thirteen-lined ground squirrels, leaping mice, etc.) and even fewer birds hibernate or sleep through the winter (woodchucks) Heterotherms are the warm-blooded creatures that hibernate during the winter.

As winter approaches, hibernating homoiotherms seek a hibernaculum and become poikilothermic. So, with a decrease in the temperature in their hibernaculum, their body temperature also decreases.

In this way, they conserve energy that would otherwise be used maintaining their body temperature and moving around. However, they differ from poikilotherm in the fact that their heat generation increases as their hibernaculum approaches the freezing point.

These animals wake up from their slumber and become more homoiothermic, if the temperature decreases more. They may find a deeper hole and return to hibernation if they are fortunate. Bears, raccoons, opossums, foxes, and squirrels do not hibernate but sleep in burrows during the winter. However, their temperature does not decrease.

Organisms With Eurythermal and Stenothermal Heat

As eurythermal animals, creatures such as humans, lizards, and amphibians can survive a wide range of temperature variations. In contrast, corals, snails, and other organisms cannot endure wide temperature fluctuations because they lack the ability to adapt to such changes. These organisms are known as stenothermal ones.

Ectotherms Versus Endotherms

Based on the interactions between organisms and external temperature, organisms are classified as either ectotherms or endotherms. Ectotherms are organisms whose body temperature is mostly maintained by external heat sources. Examples include protist, fishes, reptiles, etc. Endotherms are organisms that can generate heat inside to increase their body temperature. Examples include birds and mammals.

As the temperature deviates from the thermoneutral zone, endotherms waste an increasing amount of energy to maintain their body temperature. Endotherms generate heat at a rate under brain control. Insulator material (fur and fat) and blood flow regulation at the skin's surface result in moderate heat loss.

Functions of temperature

The temperature has the following effects on plants and animals.

1. **Impact on metabolic rate**
   Temperature influences the metabolic processes of organisms by regulating the activity of enzymes. It influences the transpiration, photosynthesis, and germination rates of plants. In addition, it governs the rates of respiration and other metabolic processes in both plants and animals.
2. **Influence on reproduction**
   a) Plants
   Temperature influences plant flowering. It also plays a crucial part in plant phenology (the study of periodic phenomena).
   b) Animals
   The temperature at which the maturity of gonads and the release of gametes occurs differs from species to species. In

rare cases, the breeding process is also affected by temperature. The quantity of eggs laid by blowflies increases with temperature by up to 32.5 degrees Celsius, and then, falls. Temperature also affects the reproductive capacity of animals.

3. **Effect on development and growth**
   a) Plants
   Extremes of hot and low temperatures are detrimental to plant growth. Low temperatures cause illnesses such as desiccation, chills, and freezing injury. Heat damage refers to the stunting and death of plants caused by extremely high temperatures.
   b) Animals
   Temperature influences the growth and development of animals. When water temperature falls below 21 degrees Celsius, corals do not thrive. The incubation period of blowfly eggs reduces as temperature rises.
4. **Effect on crossing the border**
   It is believed that temperature influences the crossing over and somatic expression of genes in animals. If the larva or pupa are kept at low or high temperatures, the wings, eyes, etc., do not grow properly.
5. **Impact on sex ratio**
   The sex ratio of rotifers and daphnids is affected by temperature. Under normal temperature conditions, daphnids produce parthenogenetic eggs that develop into females. However, as the temperature rises, they produce fertilised eggs that can develop into males or females.
6. **Impact on colouring**
   Some species of mammals, birds, and insects inhabiting warm, humid regions have darker pigmentation than those inhabiting chilly, dry climates. Low temperatures induce pigmentation darkening in *Hyla* (tree frog) and *Phrynosoma* (horned toad).
7. **Influence on morphology**
   Temperature influences the size of an organism in absolute terms. In colder climates, mammals and birds acquire bigger body sizes than in warmer regions. In colder places, poikilotherms are smaller. In colder regions, the snout, ear, legs, etc., of mammals are shorter than in warmer regions. In colder climates, bird species have wings that are narrower and more acuminate, whilst those in warmer regions have wings that are typically larger.

Precipitation

Nearly 97 per cent of the world's usable water is found in oceans, with the remaining 3 per cent found on land. This water's evaporation and transpiration result in the generation of water vapour, which at any given time accounts for less than 0.001 per cent. If this water vapour precipitated simultaneously over the entire Earth's surface, it would amount to 2.5 centimetres of rainfall.

The average annual rainfall across the entire planet is approximately 80 centimetres. Three-fourths of this precipitation falls into the oceans. However, the oceans supply around five–sixth of the water that evaporates during the hydrological cycle. The difference falls as rain on land, which eventually enters the ocean via rivers. Without this asymmetry, the land would have been considerably drier.

There are ways, in which precipitation or rain falling on the Earth's surface returns to the atmosphere.

Some water evaporates directly from the soil, from open waterways such as ponds, lakes, and oceans, and from the surfaces of things (wet from recent rain).

Some water returns through transpiration (the exhalation of water vapour through the leaves of plants; the plants absorb water from the soil through roots and transfer it to the leaves).

The combination of the following two processes is known as evapotranspiration, a temperature-dependent process. Evapotranspiration is dependent on the soil moisture content, the leaf area of the local vegetation and the temperature. Almost a doubling of evapotrans-

piration occurs for every 10 degrees Celsius increase in temperature. It is also proportional to the photosynthetic rate.

Adaptation

Adaptation refers to the structural characteristics of living creatures that evolve over time to allow them to survive and reproduce in a particular environment. In other terms, it is the capacity of an organism to adapt to its environment. An organism that is well-adapted to its environment is able to obtain the essential food and water, get appropriate shelter, and mate to continue its species.

Adaptation of Plants to Water (Hydrophytes)

A hydrophyte is a plant that is adapted to live on soggy soil, or partially, or completely submerged in water. Hydrophytes are plants that thrive in water and adapt to their environment. There are three primary categories: emerging, floating, and submerged.

Emergent Hydrophytes

Emergent plants are typically planted or found around the shores of a pond and originate from the Earth. Examples include *Nyphaea*, *Nelumbo*, *Nelumbium*, *Marsilea*, etc. Their roots are submerged, while their shoots emerge from the water. For example, *Typha* and water lilies (*Nymphaea*). The stem is long, thin, and flexible.

Mesophytes

Mesophytic plants thrive in ordinary moisture and temperature conditions. Typically, they have a robust root system and vascular bundles. They lack a mechanism for water retention, therefore, surplus water is lost by transpiration, for example, peepal, mango, rose, sunflower, and apple.

Xerophytes

Xerophytes thrive in dry, arid environments, such as deserts, and can tolerate extreme drought. Leaves are reduced to thorns or spines to prevent transpirational water loss and for defence. Examples include cactus and *Opuntia*. To decrease transpiration, the leaves (if present) and stem have a thick cuticle and waxy coating, and the stomata are also deeply seated. The stem is soft, succulent (short), spongy, and green for water storage and photosynthesis, e.g., aloe vera, etc. They have a well-developed taproot system that extends deep into the soil for water and mineral absorption.

Epiphytes

Epiphytes grow on another plant or item for physical support alone. They have no connection to the soil or other evident nutrient source. They are not parasitic on the supporting plants. Examples include orchids, vanda, polypodium, cerus, etc. Through their aerial roots, epiphytes acquire moisture from precipitation and atmospheric water vapour.

They rely on the humus in the bark of old trees, to which they cling with the assistance of their anchoring roots.

The distribution and viability of living things are regulated by both abiotic and biotic factors. Organisms have a tolerance range for each of the environmental, physical, and biological factors and when this range is exceeded by any factor, it becomes limiting.

Leibig's law of minimum: In steady state conditions, the amount of a necessary substance that is most readily available tends to become a limiting one. It only applies strictly in steady state circumstances. There should not.

It only applies strictly in steady state circumstances. There shouldn't be any factor interactions since a high concentration of a drug or an action by a factor other than the bare minimum can change how quickly another is used. For instance, strontium is used by molluscs in their shells in place of zinc.

Shelford's law of tolerance: This law states that too much of something, such as heat, light, or another limiting force, can also be problematic. As a result, the ecological range between an

organism's maximum and minimum defines its tolerance limit. Aquatic creatures typically have oxygen as a limiting element. Nutrients are a limiting component in the open ocean.

In agricultural regions and fields, phosphates and nitrates typically become limited. The crucial time for reproduction is typically when environmental variables are most likely to be limiting.

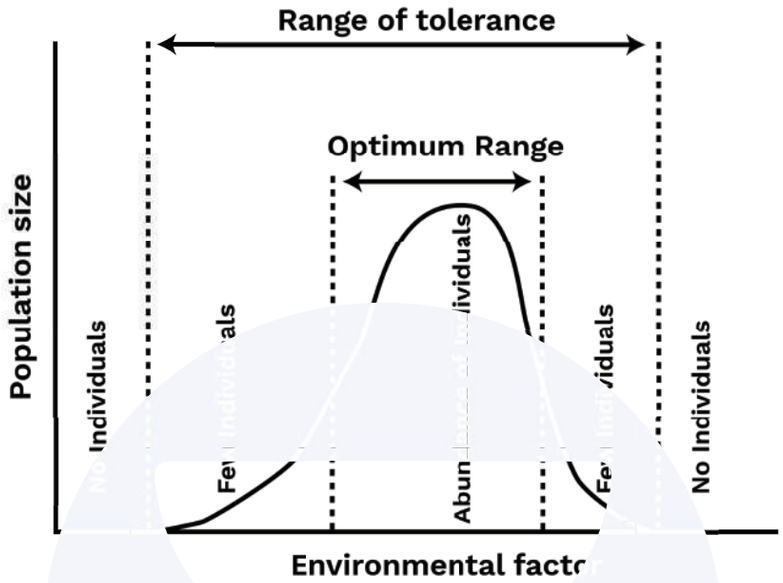

Fig. 10.5 Shelford Law of Tolerance

Three factor compensation: In order to lessen the limiting effects of temperature, light, water, etc., organisms in nature adapt to their environments and may even change them. Such factor compensation, which also occurs within species, is particularly effective at the community level, for instance, ecotypes (locally adapted populations/races).

Habitat and Niche

The habitat of an organism is the location where it resides or where one might seek it out.

Nevertheless, the ecological niche encompasses not only the physical space occupied by an organism but also its functional role in the community (such as its trophic position) and its location in the food web.

Gradients in temperature, humidity, pH, soil, and other environmental factors.

- There are three niches: Habitat niche, trophic niche, and multidimensional or hypervolume niche.
- Consequently, an organism's ecological niche depends not only on where it lives but also on how it lives.
- It comprises the total of its environmental specifications. The concept of niche is quite valuable.
- Quantitatively, it is most relevant in terms of differences across species (or the same species).
- It depends on multiple locations or times, in one or a small number of major (operationally significant) characteristics.
- The most often measured metrics are niche breadth and niche overlap with neighbours.
- Groups of species having similar responsibilities and niche dimensions within a community are known as biotic communities.

- Species that inhabit the same ecological niche in distinct geographical locations (continents and main oceans) are termed ecological analogues.

G. E. Hutchinson (1957) proposed that the niche could be conceptualised as a multidimensional area or hyper-volume within which the environment allowed a person or species to endure indefinitely. Hutchinson's niche, also known as the multidimensional or hyper-volume niche, is measurable and manipulable analytically. For instance, two-dimensional climographs that display the x and y axes of a specific bird species and a fruit fly could be enlarged as a sequence of coordinates (x, y, and z axes) to include additional environmental dimensions.

Hutchinson (1965) also differentiated between the fundamental niche—the maximal 'abstractly inhabited hyper-volume' when the species is not bound by competition or other limiting biotic interactions—and the realised niche—a smaller hyper-volume occupied under specific biotic restrictions.

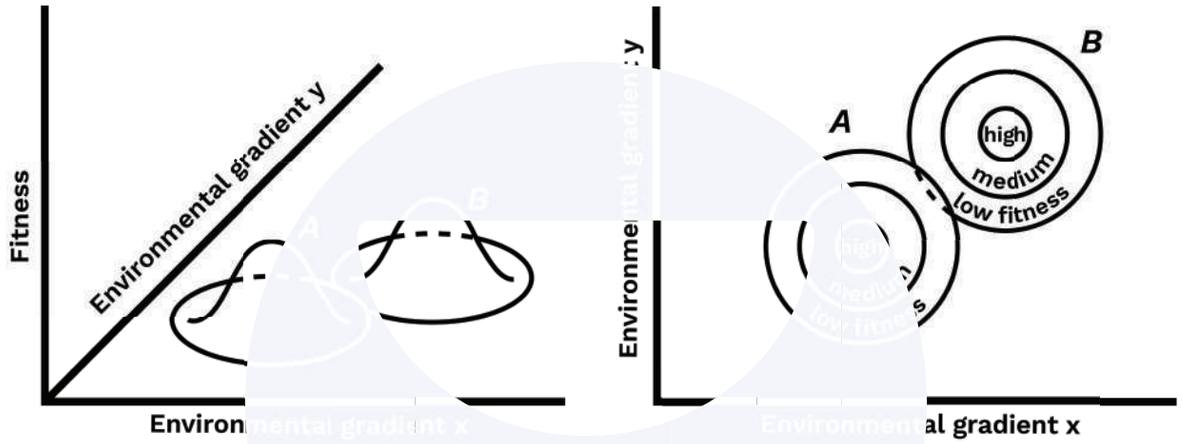

Fig. 10.6 Hutchinson Niche Concept

Variations on Ecological Niche

Charles Elton's definition of niche centred on the function of a species, such as its trophic function. His principles emphasised community similarity over rivalry.

In 1957, zoologist G. Evelyn Hutchinson offered a compromise between these two schools of thought.

Hutchinson described two specialised types. The basic niche centred on the conditions within which a species may thrive without any ecological interactions. In contrast, the realised niche assessed the existence of the population in the context of interactions, or competition.

The ecological niche concept has enabled ecologists to comprehend the roles of species within ecosystems.

The Significance of Ecological Niches

Ecologists use the ecological niche idea to assist them to comprehend the relationship between communities and environmental circumstances, fitness, characteristic evolution, and predator-prey interactions.

As climate change affects community ecology, the importance of this issue grows.

Ecological niches allow for the survival of species within their environment. Under optimal

conditions, the species will flourish and perform an important role. Without ecological niches, biodiversity would decrease and the ecosystem would be out of balance.

Ecologists refer to interspecies competition when discussing ecological niches.

Two species cannot coexist in the same ecological niche. This is because of scarce resources.

Competition influences species' fitness and can result in evolutionary changes. An animal that competes with other animals for pollen or nectar from a specific plant species is an example of interspecies competition.

In case of certain kinds of ants, the insects compete over colonies, prey, food, and water.

Competitive exclusion principle: The competitive exclusion concept helps ecologists it comprehend how species interact. According to the competitive exclusion principle, two species cannot share the same ecological niche. This is due to competition for habitat resources.

In the early and middle twentieth century, Joseph Grinnell, T. I. Storer, Georgy Gause, and Garrett Hardin were early proponents of the competitive exclusion concept.

Competition in a niche either causes each species to specialise differently in order to avoid using the same resources or causes one of the competing species to go extinct. This is an alternative perspective on natural selection. Two theories are utilised to address competitive exclusion.

Multiple species cannot coexist with the same resources, according to the R* theory, unless they separate their niches when resource density is at its lowest, populations of species most limited by the resource will be excluded competitively.

In P* theory, huge consumer densities are possible due to shared foes.

Competition exists at the microbiological level as well. If *Paramecium aurelia* and *Paramecium caudatum* are grown together, for instance, they will compete for available nutrients. *P. aurelia* will eventually eradicate *P. caudatum* for existence.

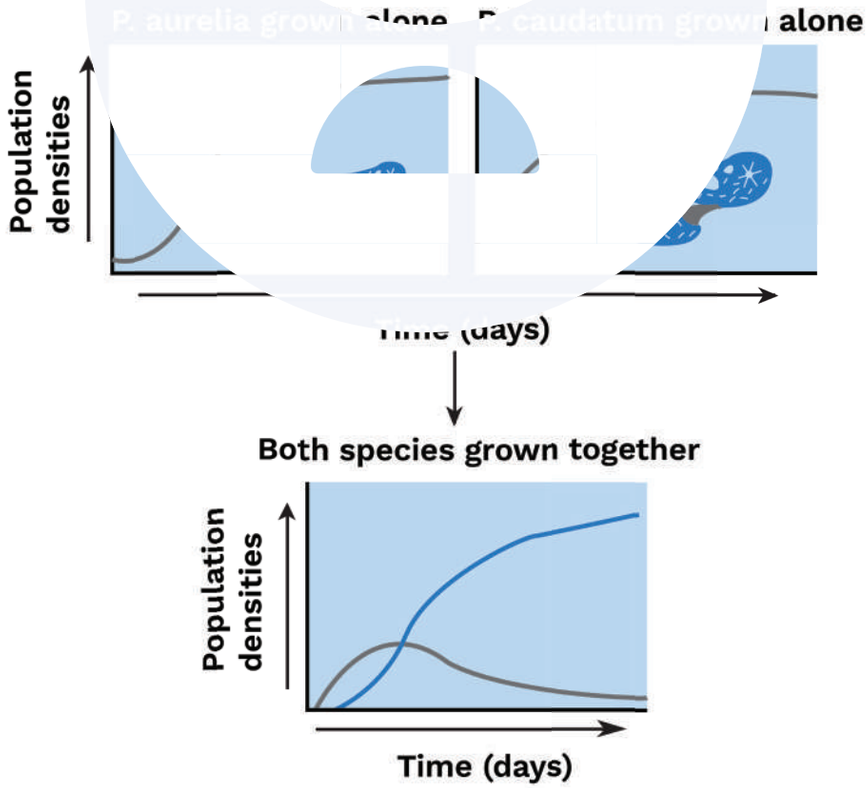

Fig. 10.7 Competitive Exclusion

Ecological Niche: 'The Sum Total of an Organism's Adaptations'

Niche identifies the 'role of an organism in its community' or the 'method through which a species makes a living'.

The niche of a species (or an individual) refers to the manner in which it interacts with its environment, hence niche is synonymous with environmental interaction.

The relationship between niches and environmental tolerance curves is close, but niches can also have behavioural elements, e.g., mode of locomotion like running, swimming, and flying, in addition to, environmental factors e.g., temperature.

Limitations: Data pertaining to niches can be used to compare the composition and organisation of various communities.

Examine changes in the behaviour or ecology of one species as a result of the presence of another.

Based on Gause's principle of competitive exclusion, niche shifts are frequently employed to analyse interspecific competition.

In order to describe or characterise the niches by correlating fitness or usage to environmental variables (abiotic and biotic), one may begin with a tolerance curve for a single environmental factor. Then, one may add a second variable that influences the fitness of the animal. After that, add a third variable that influences the fitness of the animal.

Fundamental Versus Realised Niche

The fundamental niche is the totality of conditions in which an animal (population and species) can survive and reproduce.

Realised niche is the set of variables actually utilised by a certain animal (population and species), taking into account interactions with other species (predation and especially competition).

FN and RN are sometimes referred to as pre-competitive and post-competitive niches, reflecting the conventional emphasis on the effect of interspecific competition on niches.

Nota Bene

FN ≥ RN

Varying populations of the same species may have different RN due to differences in rivals and predators.

Niche Breadth

The niches of specialised species are restricted.

Generalist species occupy diverse habitats.

These are relative terms; expert and generalist represent the extremes of continuous change in the degree of specialisation in resource utilisation, behaviour, and physiology.

The measure of niche breadth as proposed by Levins (1966) is: Breadth = B = 1/pi2.

Where, pi is the proportion of persons that utilise resource I or the fraction of each individual's diet that consists of resource i.

Due to the presence of pi in the denominator, organisms that utilise numerous resources will have a high value of B, indicating a generalist pattern of resource utilisation.

Between Phenotype and Within Phenotype Niche Breadth Components

If one is aware of the niche breadth of a population, it is not always apparent how individuals within that niche behave. People consume resources. For niche axes that have to do with food, it is a usual practice to study the stomach contents of numerous individuals and total across individuals to define the food niche of a community. This implies individuals have identical dietary habits. However, individuals may (or may not) use resources differently.

One extreme is that everyone uses the same population niche. Large is the within-phenotype component of niche breadth.

Each individual utilises a tiny portion of the population's niche. Large is the between-phenotype component of niche breadth.

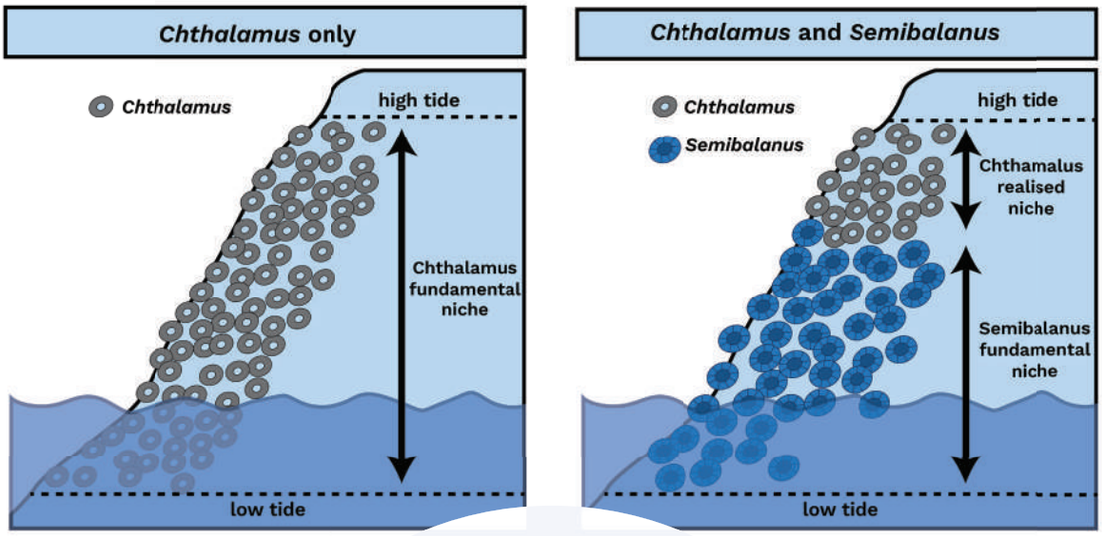

Fig. 10.8 Fundamental and Realised Niche

Nota Bene

Individual niches can be extremely similar to the niche of the entire population, or they can be quite distinct.

Individuals' niches can alter substantially over the course of a lifetime. Good instances are provided by animals with uncertain growth (e.g., lizards) in which older individuals are significantly larger and hence hunt upon larger prey. Excellent instances from creatures that undergo metamorphosis, such as tadpoles being herbivores and frogs being carnivores.

Use the degree and kind of niche overlap to evaluate interspecific competition. In general, rivalry exists when specialisations overlap and resources are limited.

Neighbouring niches indicate (indirectly) that competition may have contributed to niche divergence in the past.

Hairston's investigation into salamanders' interspecific rivalry reveals a lot of information. *Plethodonjordani* and *Plethodonglutinosis*, two species of salamander are found in the Smoky Mountains. They are divided by height, according to an observational study. Greater overlap in the Balsam Mountains may indicate that resources were more scarce there than in the Smoky Mountains.

It also implies the competitive exclusion of *P. glutinosis* in Smokys in Jordan. *P. glutinosis*, however, alters its altitude range between the two sites. Experimented with eliminating one species and observing how the other species responded.

However, for *P. jordani*, intraspecific and interspecific variance in aggressive behaviour within populations was just as significant as variation between populations. In populations of *P. glutinosus*, alpha-selection (i.e., enhanced competitive ability by the acquisition of interspecific interference mechanisms) has happened as a result of fierce interspecific rivalry. The level of intraspecific rivalry also seems to have had an impact on the evolution of aggressive behaviour.

Resource partitioning

The unique concept of resource partitioning dates back to the evolutionary diversification of species as a result of interspecific competition. The more commonplace place main organic utilisation is basically centred on the exceptional makes use of assets by using species in a specific region and no more on the precise evolutionary basis of such variances. This article investigates the second convention.

There are two types of competition between organisms for limited resources—Intraspecific and interspecific. As the prefixes imply, intraspecific competition refers to competition for limited resources among organisms of the

same species, while interspecific competition refers to competition for limited resources among organisms of different species.

When species fight for the exact same resources, one species typically has a slight advantage over the other, if only marginally. The full competition maxim asserts that total competition cannot coexist. The advantageous species will endure for the foreseeable future. The weaker species will either become extinct or shift to inhabiting a one-of-a-kind ecological niche.

Habitat Partitioning Illustrations

An aid dwelling is one method by which a species might divide resources in parts of an environment that are distinct from their rivals. A common geographical example is the distribution of lizards in the Caribbean islands. Commonly, lizards consume the same type of food, i.e., insects. Nonetheless, they might inhabit unique microhabitats within the context of their enormous habitat. For instance, a few lizards can reside on the forest floor. Similarly, some organisms may reside better within the ecosystem of trees. This classification and separation of resources are based solely on their physical location. Therefore, enabling the unique species to interact with one another more successful.

Food Partitioning Illustrations

In addition, species can coexist extra effectively based mostly on food partitioning. For instance, among species of lemur monkeys, meals can be distinguished based on their chemical characteristics. Food classification based only on plant chemistry might play a vital role. This makes it possible for unique species to coexist while simultaneously consuming equivalent yet chemically distinct meals.

Similarly, species may have a preference for distinct components of the same diet. For instance, one species may choose a unique section of a plant compared to other species, thereby, allowing them to coexist in harmony. Some species may also select the plant's leaves at the same time they select the plant's stems. Species can also divide food depending on a variety of characteristics and unique previous patterns. A species may consume the majority of its food during a specific time of the day. At the same time as everyone else, the night might be especially active.

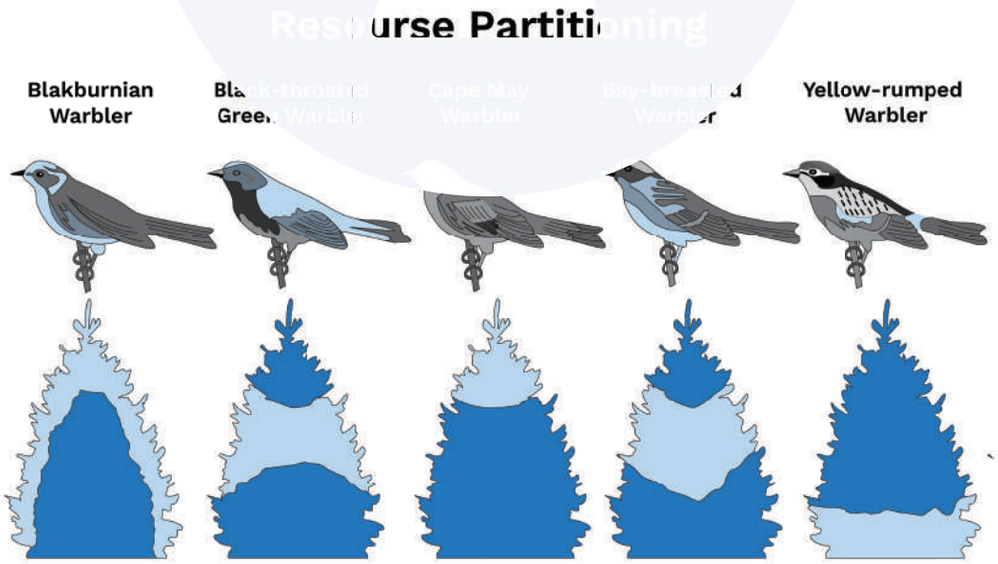

Fig. 10.9 Resource Partitioning

Long-term Consequences of Resource Division

Species can coexist for an extended amount of time within the same habitat, if they are able to divide their resources. This allows each species to survive and thrive as opposed to only one. Therefore, causing the opposite to go extinct, as in the case of total opposition. Regarding species, the sum of intraspecific and interspecific competition is significant. When unique species occupy nearly unique niches in relation to food sources, the limiting factor for population size will become intra-specific competition rather than interspecific competition.

phenomena, in which distinctions between similar species, whose geographical distributions overlap, are highlighted in locations, where the species co-occur but are diminished or lost in regions where their distributions do not overlap. This pattern is the outcome of competition among species for a restricted resource driving evolutionary change (e.g., food). The rationale for character displacement derives from the competitive exclusion principle, also known as Gause's law, which states that in order for two competing species to coexist in a stable environment, they must differ in their respective ecological niche; otherwise, one species will eliminate or exclude the other through competition.

Where species' niches overlap, the competition for resources is greatest. In the zone of overlap, a species' realised niche may be smaller than its fundamental niche due to high competition. In communities with numerous similar species, resource partitioning occurs as a result of overlapping niches occupied by similar species. These ecological interactions can exert such strong selection pressure that the trait to utilise the resource (such as the beak of the bird to ingest seeds) might change to an entirely new character over successive generations (like a smaller or larger beak better matched to the available seed food supply). This change in characteristic value is referred to as character displacement. Character displacement is an evolutionary adaptation of an inherited characteristic resulting from resource partitioning. If the feature in question lacks sufficient heritable variation for character displacement to occur, the result may be competitive exclusion, in which the more successful species outcompetes the other to the point of extinction.

Population Genetics

A population is a group of organisms of the same species that interact and comprises individuals of various ages or stages, including juveniles and adults. Most populations contain a mixture of youthful and elderly members. The demographic structure of a population is determined by counting the number of individuals at each age or stage. In addition to demographic structure, populations differ in terms of total number of inhabitants known as population size, and how closely those individuals are packed together known as population density. The geographic range of a population is bounded by physical constraints that the species can bear, such as temperature and aridity, and by the incursion of other species. Typically, population ecologists first evaluate the dynamics of population size that change over time, i.e., whether the population is expanding, contracting, or keeping static over time.

Geometric (or Exponential) Population Growth

The most fundamental method for population increase is to assume that each individual has two children and then dies, which would cause the population to double every generation. The population of a perfect bacterium with infinite resources would double with each generation.

When resources are inexhaustible, populations rise exponentially, producing a J-shaped curve. Because the number of births and deaths at each time point remains constant across time, the population growth rate stays constant. Mathematically, the growth rate is the intrinsic rate of natural increase, denoted by the constant r for the population size N. r is the population's birth rate b minus its death rate d.

The Exponential Expansion Formula

The exponential expansion equation enables us to recognise the growing pattern over time. The change in population size over time is proportional to the population size multiplied by its growth rate. Despite the fact that the value of r remains constant over time, the population in this model does not increase linearly since every individual born in a given generation reproduces. As a result, the population rapidly increases in size. In the natural world, a population expanding at such a rapid rate would rapidly deplete all available habitats and resources. Unlike the model indicated by the exponential growth equation, the environment imposes size restrictions on natural populations.

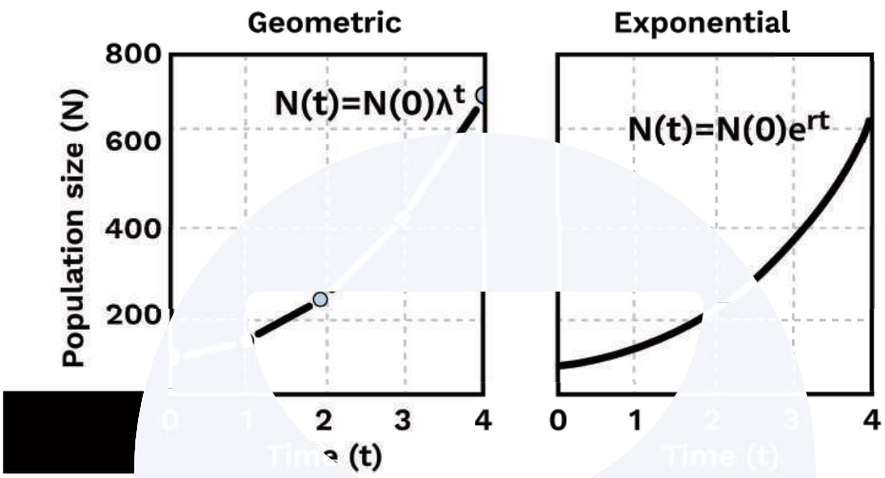

Fig. 10.9 Exponential and Geometric Growth

Logistic Population Growth Reaches a Plateau at the Carrying Capacity

To examine how resource scarcity influences population increase, we must add the concept of carrying capacity, the maximum population number that an ecosystem can support. Any individual born into this population would increase its size until the number of deaths is equal to or greater than the number of births. If the size of the population remains constant from one generation to the next, then individuals must be dying at the same pace. With exponential population growth, the population growth rate r was constant; but when a carrying capacity is imposed by the environment, the population growth rate slows as the population size increases, and growth ceases when the population hits carrying capacity.

When resources are scarce, populations expand logistically. In logistic growth, population expansion declines as resources become scarce and reach a plateau when the carrying capacity of the environment is met, producing an S-shaped curve.

We can achieve this mathematically by introducing a density-dependent element into the population growth equation, where K is the carrying capacity.

Now, the equation reveals that the population growth rate r is changed by a density-dependent factor (K–N)/K.

What happens to population increase when the ratio of N to K is small? When N is close to K? And when does the population increase the most in each generation?

Population size is controlled by variables that are either reliant on or independent of population density. There are biological and non-biological elements that can affect population size. Interspecific interactions,

such as predation, competition, parasitism, and mutualism, as well as, illness are biological variables. Environmental variables like temperature, precipitation, disturbance, pollution, salinity, and pH are examples of non-biological influences. All of these factors can affect population size, but only biological forces (with the exception of mutualism) can 'control' a population, i.e., drive it to an equilibrium density or carrying capacity. Mutualism does not control population size among biological factors since mutualism promotes population growth through beneficial interactions with another species.

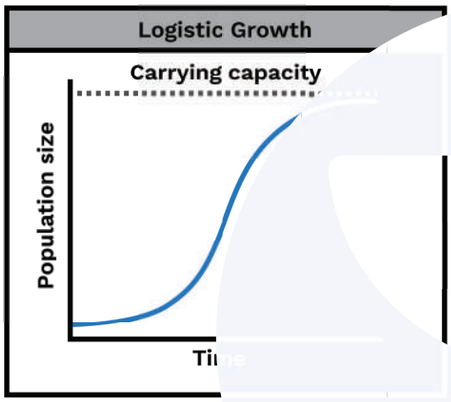

Fig. 10.10 Logistic Growth Curve

Different biological processes, such as competition and predation, regulate population increase in dense and sparse populations. For instance, communicable diseases do not spread rapidly in sparsely populated areas, but in densely populated areas, such as college dormitories, sickness can spread rapidly through individual contact. In the following ways, population control is heavily dependent on population density:

Territoriality: When space is a scarce resource, maintaining a territory allows an individual to capture enough food to reproduce. The transmission rate of disease frequently depends on population density.

Predation: Predators may target numerous prey.

Toxic waste: As populations expand, metabolic by-products build.

In order to identify evidence of density regulation, it is necessary to conduct a field or laboratory experiment that manipulates density and measures the population growth response. Often, a (easier to quantify) proxy for population increase, such as survival or reproductive output, is substituted for births and deaths that influence population growth. The negative correlation observed in the graph is evidence of density dependent population regulation, i.e., higher density results in decreased survival.

Metapopulations

Metapopulations are populations of a single species that are connected by migration.

A species that is ecologically related to a specialised, patchy habitat may adopt the patchy distribution of the ecosystem, with separate populations dispersed at various distances. This is true, for instance, for species that inhabit marsh areas, alpine zones on mountaintops, specific soil types or forest kinds, springs, and numerous other similar environments. Periodically, organisms can disperse from one group to another, promoting genetic exchange between populations. This collection of distinct but interconnected populations, with each population inhabiting its own distinct ecological patch, is known as a metapopulation.

Dispersal levels among the constituent populations of a metapopulation may vary considerably. A large or overpopulated population patch, for instance, is unlikely to be able to support significant immigration from nearby populations; yet, it can serve as a source of dispersing individuals who will move out to join other populations or form new ones. In contrast, a small population is unlikely to experience a high rate of emigration; rather, it is more likely to experience a high rate of immigration. A sink population is one that requires net immigration to sustain itself. Therefore, the quantity of genetic exchange between source and sink populations relies on the size of the populations, the carrying capacity of the habitats where the populations

are found, and the mobility of people across habitats. Understanding the arrangement of patches and their constituent populations within the metapopulation, as well as, the ease with which individuals can travel between them is crucial for defining population diversity and conserving the species.

Biological Characteristics and Their Evolution

A population's members endure a life cycle consisting of birth, growth and development, maturation to adulthood, and eventually senescence. How energy is allocated to these various aspects of an organism's survival is referred to as its life history, and this energy allocation generates characteristic life history traits. These traits influence survival and reproductive output—size at birth, age at maturity, size at maturity, number and size of offspring (fecundity), reproductive value, lifespan, and senescence, which we will define as the decline in fecundity with age. Life history theory explains how evolution optimises these survival and reproductive traits in different populations, influencing parameters, such as how large and fast individuals grow when they reach sexual maturity, how many offspring they produce each time they reproduce, how often they reproduce, and when they die, etc.

Survival and reproduction are 'optimised' rather than 'maximised.' This is due to the fact that when evolution increases one of these features, such as parental survival, the outcome is typically a drop in reproduction, such as the number of offspring produced per year, and vice versa. This optimisation results in a life-history trade-off, shown as a negative correlation between survival and reproduction. The prevailing hypothesis regarding trade-offs between survival and reproduction is that energy, which is the limiting factor. Organisms have limited energy. So, if they devote energy for survival, they have less available for reproduction. As a result, certain creatures, such as the chinook salmon, reproduce only once in their brief lifetime, but others, such as the Atlantic cod and humans, breed repeatedly.

Life history trade-offs between reproduction and survival can be influenced by a population's growth rate and the carrying capacity of its environment. Remember that r is the intrinsic rate of natural increase of a population and K is the carrying capacity of the environment:

Life history features that promote growth rate (live fast, die young) are referred to as r-selected. These traits include a large number of offspring, a small body size, early sexual maturation, wide dispersal of offspring, little parental care, and a short life span. Included among the species with r-selected life history features are insects, microorganisms, numerous type of plants, and tiny mammals, such as rodents. These species tend to exploit ecological niches where they are not limited by carrying capacity, in part because each individual offspring has a low probability of survival despite the fact that they produce numerous offspring. Their population sizes can fluctuate substantially over brief time periods.

K-selected life history qualities include traits that are virtually the reverse of r-selected traits, such as relatively small number of offspring, relatively big body size, delayed sexual maturation, offspring that require a high level of parental care, and prolonged life span. Species having K-selected life history features include huge creatures such as a variety of large mammals, reptiles, and birds. In the absence of natural disasters, epidemics, or other cataclysmic events, the population size of these species tends to be relatively steady and close to the carrying capacity.

Regardless of whether a species has more r-selected or K-selected features, individuals at different times of their lives can have varying reproductive success rates. The reproductive value of a given-age individual is the average number of offspring produced at that age. Reproductive value is controlled by the probability of survival and the probability of successful reproduction, and it increases at the commencement of sexual maturity before declining with age. The age classes and life cycle stages with the highest reproductive value are those where natural selection is most effective.

Lifetable

Life tables are a useful tool for analysing the effect of age structure on the growth trajectory of a population.

Population demography is the study of a population's changing numbers and rates over time. The life table is the fundamental methodological component of demography. Population ecologists use life tables to investigate age-specific population features such as survival, fertility, and death. In conservation activities (such as reintroductions or pest reductions) when ecologists would like to know how well a threatened or transplanted population is doing, these data can be crucial.

The number of people who survive from one age group to the next is determined by life tables. Cohort life tables track one group of individuals born at the same time, referred to as a cohort, until their deaths. This method of demographic analysis involves the following assumptions. The population sample of each age group is proportional to that group's population size.

Age-specific mortality rates remain stable throughout the timeframe, indicating that succeeding cohorts will exhibit a similar birth-and-death pattern.

Age (x)	Number Alive (nx)	Survivorship (1x)	Age-Specific Fecundity (mx)	Survivorship x Fecundity (1xmx)
0	100	1	0	0
1	25	0.25	0	0
2	12	0.12	2	0.24
3	8	0.09	5	0.45
4	6	0.06	5	0.3
5	4	0.04	5	0.2
6	3	0.03	2	0.06
7	2	0.02	2	0.04
8	0	0	0	0

Fig. 10.11 Life Table

The top row of the life table depicts the cohort's year of birth, and each successive row displays the cohort one year older. Assuming that the unit of age (x) is years, the number of individuals still alive (nx) column reveals that not every individual survives from one year to the next. Survival turns mortality into a fraction of the original cohort that is still living (lx = nx/n0). Age-specific fecundity is the average number of offspring born to individuals of each age, which cannot be computed from other information supplied in the table and must be approximated from statistics.

Here is the greatest part and the reason we bother to collect age-specific survival and fertility data. If (1) and (2) are true, then the total of the product of survivorship and fecundity at each age yields the population growth parameter to R0 (pronounced R-zero), which is the net reproduction rate. When R0 is greater than 1, the population produces more children than it loses to deaths. In other words, population growth is occurring.

Is the population increasing, decreasing, or stable? At what age is fertility at its peak? What about the survival rate?

Patterns of age-specific survival are predictive of the general life history of a population due to life history trade-offs. While a life table displays the survival rate numerically, it is difficult to discern patterns from columns of data. Ecologists generate survival curves by charting values against time.

In survivorship curves, population biologists search for three types of patterns.

In populations with low mortality in younger age classes and extremely high mortality as an individual ages, Type I curves are observed.

The populations represented by Type II curves have a constant mortality rate regardless of age. Type III curves are observed in populations with a high mortality rate among younger age groups and a very low mortality rate among the elderly. In order for populations with a Type III survivorship curve to maintain a constant size, substantial birth rates are typically required. High birth rates ensure that sufficient offspring survive to reproduce, hence sustaining the population. In contrast, populations with a Type I survivorship curve often have modest birth rates since the majority of offspring live to reproduce, but those with extremely high birth rates have exponential population expansion.

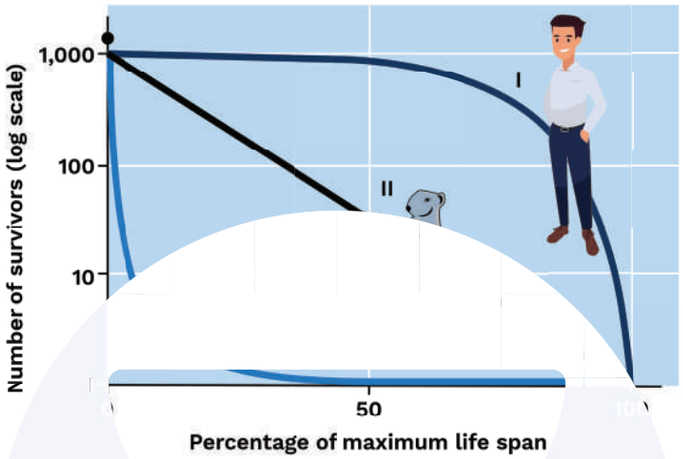

Fig. 10.12 Survivorship Curve

Population Density

It is defined as the number of people relative to a specific unit of space. It is typically stated as the number of individuals or biomass/area or volume, such as 100 humans per square kilometre or 4000 crustaceans per cubic metre.

Techniques for calculating population density

Methods for measuring the population density of organisms include the following.

1. **Overall counts:** This refers to the total number of organisms in a given area, especially in big or dense populations. Observable organisms conducting a census of the human population, whales in a region of an ocean, etc.
2. **Sampling techniques:** In this technique, a tiny fraction of the population is counted and utilised to estimate the population as a whole. Two methods exist for sampling.
   a) **Use of quadrate:** Count all the people on several quadrates of known size. Size and apply the mean to the entire region. The variables in form and size of quadrate type investigated creatures may be round, triangular, or square in shape.
   b) **Capture-recapture method:** In 1898, the scientist CGJ Peterson created the Peterson technique, which is a simple sort of population approach. This technique is utilised to count larger animals such as birds, fish, etc. The creatures are captured, tagged, and then released into their natural habitat. The following day, animals are recaptured to determine the population density.

At any given time, the population will contain both marked and unmarked individuals. The fraction of marked individuals in a subsequent sample is used to estimate the population size. Suppose 100 fish are taken, marked, and then, flown back into the pond. After some time, another 120 fish, including 30 marked fish, were taken. The population size was determined by the formula.

$$\frac{\text{Marked animal in second sample}}{\text{Total caught in second sample}} = \frac{\text{Marked animal in first sample}}{\text{Total population size}}$$

Thus, the overall population size projected is 400. Sometimes assessment of absolute density of a population is challenging. So, it is simple to determine the relative density. The relative density never offers an estimate of density, rather it is an index of plenty that is more or less accurate. Relative density can be calculated using the following methods.

Trap: It is mainly employed in capture-recapture procedures but also used to measure relative density as the number of individuals caught per day per trap.

Quantity of faecal pellets: By counting the number of faecal pellets in an area, the population size can be determined, for instance, population of rabbits, deer, etc.

Vocalisation frequency: By examining the calls of animals in given time length, index of population size can be determined. The number of pheasant sounds heard every 15 minute in the earlier times has been used as a measure of the size of the pheasant population.

Feeding capacity: Population density can be counted by estimating the amount of food consumed by animals before and after treatment. For instance, the amount of bait consumed by rat/mice before and after toxication can be used to determine an index of change in density.

Natality

It is defined as a population's birth rate. In general, natality refers to the formation of new individuals through hatching, germination, and fission.

Types of natality

There are two categories of natality.

Absolute or physiological natality: It is defined as the physiological capacity of organisms to produce viable offspring that produce the greatest number of new people possible under ideal conditions. It is extremely difficult to obtain absolute natality in natural populations, although it is possible. It can only be noticed under favourable conditions or when significant limiting factors are momentarily absent.

It is non-operative, if a limited number of paramecia are placed in a culture medium. They will achieve maximal natality by replicating at maximum reproductive rate under favourable conditions rate. It is an advantageous for two reasons.

1. It gives a benchmark for comparing actual natality.
2. It is useful for establishing equations to determine the rate of growth of a given population.

Ecological versus actual natality: It is described as population growth under ecological conditions or real environmental conditions. It changes depending on a population's age, composition, size, and physical environment circumstances.

Nativity is expressed as: Nn/t = Absolute/rough birth rate

Or Nn/Nt = specific natality/ birth rate, often known as the number of new individuals/ unit time/ unit population.

N = Population total or reproductive portion population

Nn = Number of new people added to the population

t = Time elapsed during population change

Since population growth is proportional to the number of women in a population, the age-specific fertility rate is dependent on the number of females.

The birth schedule only accounts for females who give birth to females. The age-specific schedule is derived by calculating the average number of female births per group of females. The crude natality or birth rate is represented in terms of population size, such as 40 births per 1000 people. The particular fertility rate will be 4 per cent. The natality rate is the number

of offspring per female per unit of time. The magnitude of the natality rate depends on the organisms under study. Some species reproduce annually, while others do round the year. Some reproduce few offspring, while others generate large numbers. For example, fish typically lay a few thousand eggs, frogs generate a few hundred, birds lay between one and 20 eggs, while mammals have few offspring (between 1 to 10). Typically, the birth rate is inversely proportional to parental care.

Age distribution

- It is the total number or per centage of a given population's members in each age group. The age structure of a population influences its characteristics. Age distribution has an effect on natality and mortality
- A population's reproductive status can be determined by its age distribution ratio.
- Age is usually stated in days, months, or years, but also classified in pre-reproductive, reproductive, and post-reproductive categories. The future is also determined by the age structure.
- The population with more members in the reproductive period than the post-reproductive phase demonstrates an increasing population. However, other plants and animals, such as insects and fish, do not. They do not possess a post-reproductive phase. For instance, bamboo displays mass flowering and then fruiting.
- A population roughly has an equal distribution of post-reproductive and reproductive individuals.
- Individuals demonstrate the stability of a population.
- A population that is dwindling will have a substantial number of aged or post-reproductive individuals.
- A population often attempts to maintain a consistent age distribution.
- The size of a population reflects its current reproductive condition.
- Most animal populations are around 2:1 steady. After achieving a steady age distribution, changes in natality and mortality have a short-term impact on population stability, which attempts to revert to normal.

The logistic model and its variations assume that a population will stabilise at its carrying capacity, which regulates population density. There is a maximum population density established by the environment in which the populace is controlled. The significance of governance in population has been a bone of contention among many ecologists for more than a decade.

What governs a population? Krebs (1985) described this phenomenon.

Characteristics of variables that affect population density state that population density may only be grown by births or deaths, mortality or emigration.

These elements may be density-dependent or density-independent.

Density-dependent Factors

Density-dependent factors show limits on population growth—those resulting from intraspecific competition representing dependency on density. Typically, the organisms that thrive best are those that are suitable for competing with another organism based on density or population size. Consequently, the behaviour of conspecifics can exactly serve to restrict the environment (e.g., eat less meat, favoured meals, get preferred housing, etc.). Behaviours that serve to restrict the habitat of conspecifics—such as eating, excreting waste, and consuming non-food resources, occupying space, and defending territory are individuals who determine carrying capacity. They are mentioned as density dependent due to the fact that the larger the density of population, the larger their consequences will be. Density-dependent factors can exert their influence by diminishing birth rates, rising death rates, and generation extension occurrences, or by compelled migration of conspecifics to regions. The illness impact on a population can be density-dependent, if the disease transmission rate depends on a specific level of population density. It is stated that the death rate rises

as population density increases. For instance, the birth rate that decreases with increasing population density.

Density-dependent rates are one such unfavourable response. Alternatively, the birth rate or death rate that remains constant regardless of population density to be density-independent. Negative feedback discourages population increase without limits. Predation can also be reliant on population density, as predators change prey choices frequently to match whatever prey creatures are most abundant in a specific habitat. Many predators, for example, display to begin concentrating on a different activity especially prevalent species of prey when they become energetically efficient to do so.

Density-independent Factors

There are impacts on population sizes (or structures) for the same degree, irrespective of population size. These might be things, such as abrupt weather changes. In the long term, many populations remain relatively stable. Stable in size and likely near carrying capacity density-dependent factors that influence the capacity. However, superimposed atop this general stability are variations on a short-term basis caused by density-independent factors.

Age Pyramids

The age distribution of a population can be depicted as polygons or age pyramids, where the relative width of the succeeding horizontal bars represents the number of persons or the proportion of the population in each age class. There are three recognised forms of pyramids. A bell-shaped pyramid with a broad base symbolises a growing population.

The pyramid in the shape of a dome represents an average proportion of young and old folks.

The urn-shaped pyramid represents a diminishing population with fewer pre-reproductive individuals.

Age distribution is useful for the management of wildlife. A low pre-reproductive phase to reproductive phase ratio suggests a poor reproductive season. Nevertheless, changes in age distribution alone do not imply changes in survivability or fertility, and therefore should not be used to anticipate population trends.

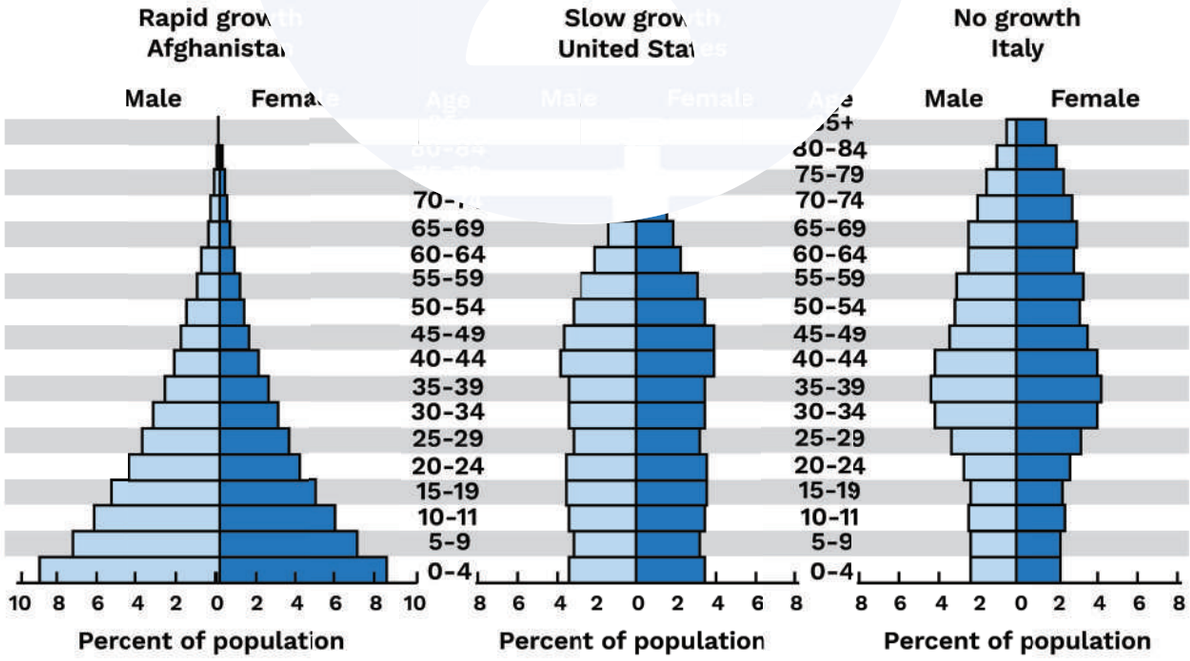

Fig. 10.13 Age Pyramid

Sexual Representation

Individuals within a population differ in a number of aspects, including age, sex, reproductive state, and health. Sexual reproduction is utilised by eukaryotic creatures. Some species have the potential to reproduce asexually, but they also have sexual reproduction capabilities to maintain genetic diversity in the community. Sex ratio is the proportion of male to female persons within a population.

The sex ratio can be divided into two categories.

1. **First sex ratio:** It is the proportion of males to females at the time of conception, and it tends to be male-dominant.
2. **Secondary sex ratio:** The ratio of males to females at birth. This 1 : 1 ratio typically favours males at early ages but has flipped to favour females at older ages.

In case of humans, the ratio of males to females at birth is also greater than females (52 per cent), but as parents age, the ratio of females to males increases. Similarly, men outnumber females in birds, cattle, and rabbits, although males account for only 49 per cent of the domestic chicken, sheep, and horse population. However, there is significant variance in the secondary sex ratios of vertebrates. For instance, one male always dominates a breeding group of 30 females in the Alaskan fur seal, and the male sex ratio approaches 3 per cent.

Other adult males reside on the outskirts of the breeding groups and have a high mortality rate. During nesting season, the mortality rate of female birds is higher than that of males in certain species.

The shift in sex ratios from 1 : 1 to uneven in older age may be a result of physiological and behavioural characteristics that affect mortality differently between sexes. With birds, females assist males in building the nest, defending the territory, incubating the eggs, brooding and feeding the young, making them more susceptible to predation and other threats. Adult males in mammals and adult females in birds consume more energy and are more susceptible to predation, which may account for the disparity in sex ratio among older age groups.

In sexually mature animals, there is a process of partner selection. The term for this process is mating system. The mating system is classified as monogamy since males and females are paired and their relationship is sustained for an extended period of time. Prostitution is an alternative mating system in which males and females mate with multiple individuals of the opposing sex without forming a relationship between them. Monogamy is most prevalent among birds and uncommon among mammals. In monogamy, both parents exhibit cooperative behaviour to raise their children. During the breeding season, the majority of bird species are monogamous because their young are defenceless and require food, warmth, and protection. Female mammals produce milk for the nourishment of their offspring. Males frequently contribute little or nothing to the survival of their children, so it is in their best interest to mate with the greatest number of females feasible.

In many species of monogamous birds, including bluebirds (*Sialia sialis*), the female or male may 'cheat' by mating with others while maintaining the reproductive relationship with the primary mate and caring for the young in order to increase their chances of contributing their gene to the gene pool. Polygamy is the acquisition of two or more mates by one individual. One male and numerous females or one female and several males can be involved. There is a pair bond between each individual and its mate. Generally, the individual with several mates is not involved in child care. Various types of polygamy are caused by environmental and behavioural factors. In polygyny, a single male mates with multiple females. In polyandry, a single female mates with many males. Polyandry is fascinating since it is outside the norm. This

system is best developed in three bird groups: jacanas, phalaropes, and some sandpipers. The female competes for and defends the male's resources. Each clutch of eggs produced by the female is fertilised by a different male. The male initiates incubation and becomes inactive sexually.

Exponential and Logistic Expansion

To comprehend the various models used to portray population dynamics, let us first examine a generic equation for the population growth rate (change in the number of individuals over time).

dN/dt = rN

Where N-population size, t-time, and r-intrinsic rate of natural increase.

The value of r is the maximum when resources are not limiting. Since the curve drawn between population size (Y-axis) and time (X-axis) is J-shaped, it is also known as J curve or J-shaped growth model (Figure 5a).

Here, dN/dT represents population's growth rate, N represents size, and r represents per capita rate of increase.

The preceding equation is relatively generic; we can develop more specific variants to explain exponential and logistic growth models.

Exponential growth happens when the per capita growth rate maintains a constant positive value regardless of population size.

Logical growth happens when the per capita growth rate decreases when the population approaches its carrying capacity.

Exponential Expansion

Laboratory-grown bacteria are a good illustration of exponential development. In exponential growth, the growth rate of a population grows proportionally to its size over time.

Let us examine how this operates. Bacteria reproduce via binary fission (splitting in half), and the duration between divisions for many bacterial species is approximately one hour. To illustrate exponential growth, let's begin by introducing 10^3 bacteria in a flask containing an infinite supply of nutrients.

Each bacterium will divide producing 2×10^3 bacteria (an increase of 10^3 bacteria).

After two hours, each of 2×10^3 bacteria will undergo cellular division to form 4×10^3 bacteria (an increase of 2×10^3 bacteria).

Each of the 4×10^3 bacteria will split after three hours, yielding 8×10^3 (an increase of 4×10^3 bacteria).

The essential idea underlying exponential growth is that the population growth rate—the number of organisms added with each generation—grows as the population size increases. And the outcomes might be dramatic: like after one day (24 divisions cycles), our bacterial population would have increased from 1 billion to almost 16 billion! A J-shaped growth curve is produced when the population size, N is plotted over time. r is the maximum per capita rate of rise under optimal conditions for a particular species, and it varies from species to species. For example, bacteria reproduce far more rapidly than humans and would have a greater maximum per capita growth rate. The following equation expresses the greatest rate of population expansion for a species, often known as its biotic potential.

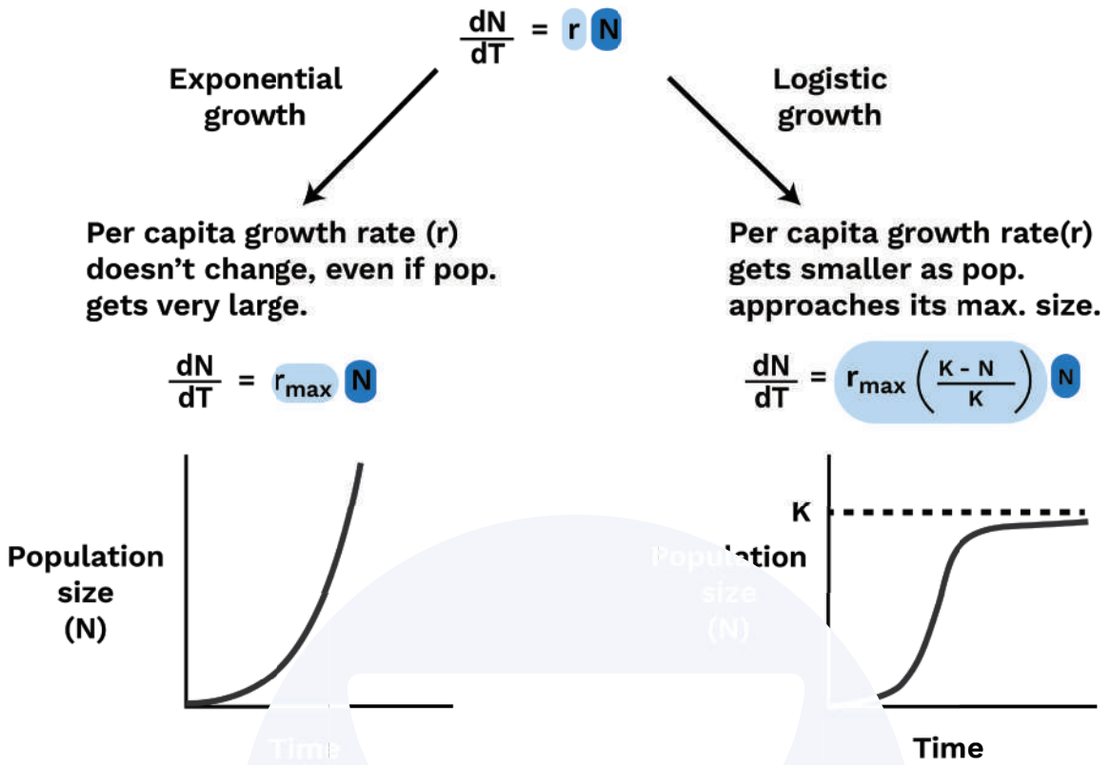

Fig. 10.14 Growth Curve and Equations

Logistic Expansion

Since it requires an unlimited quantity of resources, exponential development is not a particularly sustainable condition (which tends not to exist in the real world).

If there are few persons and many resources, exponential growth may persist for a time. When the population reaches a certain size, resources begin to deplete, limiting the growth rate. The growth rate will eventually level out, forming an S-shaped curve. Carrying capacity, or K is the population size at which it levels out, which signifies the maximum population number an environment can support.

Using r (per capita growth rate) that depends on population size (N) and how close it is to carrying capacity (K), we can theoretically simulate logistic growth.

$$\frac{dN}{dT} = r_{max} \frac{(K-N)}{K} N$$

What variables influence carrying capacity? Essentially, any vital resource for the survival of a species might operate as a boundary. Water, sunlight, nutrients, and growing space are essential resources for plants. Important resources for animals include food, water, shelter, and nesting space. Due to the scarcity of these resources, members of the same population engage in intraspecific rivalry (intra- = inside; -specific = species).

When populations are considerably below their carrying capacity, intraspecific competition for resources may have little effect because resources are abundant and all individuals may receive what they require. However, as the population grows, so does the competition. In addition, the accumulation of waste products can impair the carrying capacity of an environment.

Species Interaction

Biological interactions originate from the fact that creatures in an ecosystem interact with

one another; no organism is an autonomous entity in the natural world. Distanced from its environment. It is a component of habitat replete with live and non-living things which engage in some form of interaction. An interaction between an organism and its surroundings is important for the survival of the organism and the overall functioning of the environment. Sign-mediated interactions involving molecules serve as defining characteristics of communicative interactions. Ecological interactions are the relationships between organisms in an ecological community. These relationships can be classified in numerous ways.

Classes of interactions are based on the effects on their causes, the interaction mode of operation, and the relationships between two species. These characteristics also vary considerably in terms of time and intensity. Species may cross paths once in a generation (such as pollination) or entirely within others (e.g., endosymbiosis). The effects may vary from one species consuming another (predation) to mutualism benefit (mutualism). The interactions between species do not need to be through personal interaction.

Effect		Type of interaction
0	0	Neutralism
-	0	Amensalism
+	0	Commensalism
-	-	Competition
+	+	Mutualism
+	-	Predation or Parasitism

Fig. 10.15 Species Interaction

The level of benefit or harm is not discrete, such that a contact can range from being trivially damaging to extremely harmful. It is essential to remember that all exchanges are not always static. In numerous circumstances, two different species will interact differently in different conditions. This is especially true, but not limited to instances, where animals have multiple and significant stages of life.

Neutralism

Neutralism denotes the relationship between two individuals—species that interact but have no effect on one another. It explains interactions in which the fitness of one organism has no effect whatsoever on that of the other. True neutralism is quite improbable and impossible to prove. When addressing the complex, one can observe networks of interactions offered by ecosystems and cannot affirm categorically that there is a benefit or rivalry between two species. True neutralism is uncommon or non-existent, although its usage is extended to circumstances in which interactions are only insignificant or inconsequential.

Amensalism

Amensalism involves one species interfering with the other, i.e., hindering the accomplishment of the other without being influenced in a favourable or negative manner by the presence of the other. This is an example of symbiosis. Typically, this happens when one organism releases a chemical molecule as part of its metabolic process. A typical metabolic process that is harmful to another organism. The bread mould, *Penicillium* is a typical illustration of amensalism. *Penicillium* secretes penicillin, a substance that is lethal to bacteria. The second illustration is the black walnut tree (*Juglans nigra*), which exudes the chemical juglone. It kills or affects some species of surrounding plants. This interaction may still boost fitness. However, by removing the non-harmed creature, no harm is caused. In this regard, the obstructing organism can be reported to be adversely impacted by the other's existence, making it a positive-negative interaction. Antibiosis or allelopathy similarly explains this interaction.

Competition

Competition is the interaction of individuals or groups of populations that is damaging to both. Synnecrosis is an instance in which the interplay between mutually destructive to the point of causing death, as in a few instances of

parasitic partnerships. It is a rare and valuable item.

Antagonism

An association between organisms when one benefits at the expense of the other is referred to as antagonism in ecology. Natural selection has favoured species that can efficiently collect energy and nutrients from their surroundings as life has evolved. Organisms can become the targets of antagonistic interactions because they are self-contained, concentrated packets of energy and nutrients. Although it is usually assumed that antagonism only exists between distinct species, it can also arise within the same species through cannibalism and competition.

Understanding the various hosts or prey that different species assault is one approach to comprehend the diversity of antagonistic interactions. Attacks by carnivores, herbivores, and fungivores are all examples of predation. Other species are omnivorous, consuming a variety of different types of flora, fauna, and fungi. But there are some universal similarities in how animals interact, regardless of the foods they consume. Grazing, predation, and parasitism are the three main ways that species consume one another. The parasite feeds and survives off of its host, frequently reducing but not completely eliminating the host's capacity for survival. Grazing species frequently switch between two or more species in their diet without directly harming them. They are less dependent on their food source than parasites are. However, predators hunt and kill members of other species for food.

Different Competitions

The term defines the various direct and indirect processes for competition, respectively. These processes work for both intraspecific and interspecific rivalry.

- **Interference competition**: This type of rivalry arises directly between individuals as a result of hostility, etc., when those individuals obstruct others' ability to establish themselves physically in a particular area of the environment or to hunt, survive, or reproduce. Red deer male-male rivalry during the rut is an illustration of interference competition within a species.
- **Exploitation competition:** This type of rivalry is mediated by an intermediary shared limiting resource. For instance, they compete for space or the resource(s) depletes the amount that is available to others.
- **Indirect competition:** Competition between two species that are both preyed upon by the same predator occurs in this situation. For instance, predator C feeds on both species A and B. Because more As would mean more Cs, which in turn would hunt more species B, an increase in species A would result in a decrease in species B.
- **Intraspecific competition:** When members of the same species compete for the same resources in an environment, this is known as intraspecific competition (e.g., food or nutrients, light or space). For instance, two trees that are growing close to one another will compete for soil moisture and nutrients, as well as, sunlight. As a result of receiving fewer resources, children typically do worse than if they had grown independently.

Competition between members of different species that share a limited resource in the same space is known as interspecific competition. Reduced fecundity, growth, or survival may occur in at least one species if the resource is unable to support both populations. Competition between species has the power to influence populations, communities, and the development of coexisting species. Cheetahs and lions are two examples of creatures that are badly influenced by the presence of the other since they would have less food. This is because both species feed on comparable prey. In actuality, lions occasionally steal cheetah-cheated prey.

Lotka–Volterra Model

The Lotka–Volterra equations, commonly referred to as the predator-prey equations, are two first-order non-linear differential equations that are frequently used to describe

the dynamics of biological systems in which two species interact as either prey or predator. The Lotka–Volterra model makes a number of assumptions about the environment and the evolution of the predator and prey populations that are not always true in nature. The population of prey always has access to plenty of food. The size of the prey population is the sole determinant of the predator population's food supply. Population growth is inversely correlated with population size. The environment does not shift in favour of one species during the process, and genetic adaptation has little impact. The appetite of predators is insatiable.

The growth equations for the two species are as follows, if one species uses some of the other's resources.

For species 1 - $\frac{dN_1}{dt} = r_1 N_1 \left(\frac{K_1 - N_1 - \alpha N_2}{K_1} \right)$

For species 2 - $\frac{dN_2}{dt} = r_2 N_2 \left(\frac{K_2 - N_2 - \beta N_1}{K_2} \right)$

Every population has a specific equilibrium level or K. Competition factors with coefficients denote the impact of species 1 and 2 on each other, accordingly. The population sizes of species 1 and 2 are N_1 and N_2, respectively, whereas their individual growth rates are r1 and r_2, respectively.

1. One new individual of species 2 has a 1/K1 inhibitory effect on itself and a 1/K1 inhibitory effect on the growth of species. Any one of the competing species' growth will halt once it reaches its carrying capacity, which is the sum of its own and the numbers of the other species.

   Thus, species 1 stops growing when

   $N_1 + \alpha N_2 = K_1$

   Similarly, species 2 stops growing when

   $N_2 + \beta N_1 = K_2$

   The two species system will be at equilibrium only when the stoppage of growth coincides for the two species simultaneously, that is, when

   $dN_1/dt = dN_2/dt = 0$

2. N_2 is equivalent to K_1/when N1 is a straight line and depicts all possible number combinations at which species 1 will reach its maximum size. The arrow at X indicates that if N_1 and N_2 are mixed, N_1 will drop. Similar to how it is represented by the arrow, N_1 will rise at a mix-up at Y.

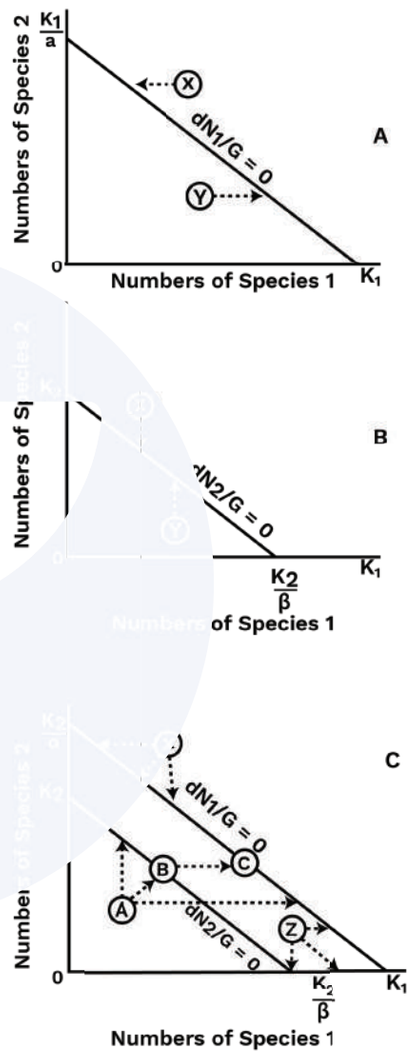

Fig. 10.16 ZPG Line of Lotka–Volterra

The Predator-prey model of Lotka–Volterra is a straight yet useful model. This model makes the assumption that the population of prey determines how many predators are there are (an increase in birth rate). For instance, if there are a lot of mice in a paddy field, foxes would consume a lot of mice and produce

a lot of young. The foxes will not be able to reproduce, if there are no more mice.

In contrast, because the predator population affects the prey mortality rate, the amount of prey would rely on it. For instance, if there are few foxes, the majority of mouse pups would grow. The mice would survive longer, even the older ones. As a result, prey are limited by predators, and predators are limited by food.

At any point along line C, the predator population exhibits neither growth nor reduction (dN predator/dt = 0). The population of predators will drop at any point to the left as a result of scarcity of food.

A similar graph can be made for the population of prey; at any point on line D, the population of prey will remain the same (dN prey/dt = 0).

3. By combining the two diagrams, one can analyse the system's behaviour and find that at point E, dN predator/dt and dN prey/dt are both equal. The system is currently in balance, with neither population increasing in size. One population would, however, be drawn away from this point in any natural system.

   The deep arrows forming a circle around E indicate the likely outcomes of the system. The population would rise in the quadrant indicated by A, and the system would migrate to the upper right quadrant. In this case, the tendency would be for the predator population to continue growing while the prey number would decrease. Once in the upper left quadrant, both populations would start to fall as the system moved there. Eventually, the system would go back to A.

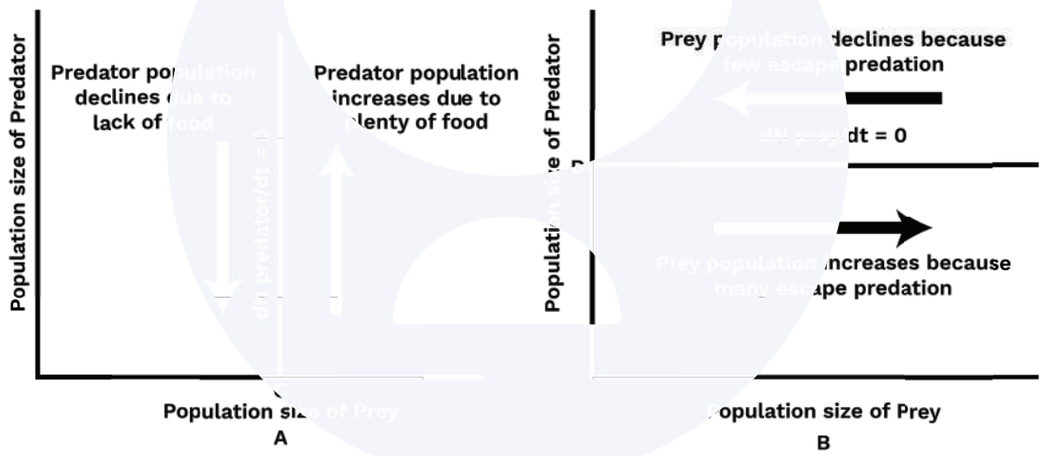

Fig. 10.17 A) Predator Population B) Prey Population

Social Ecology

The definition of community ecology is quite similar to that of synecology. Community is a very old notion that dates back to Theophrastus's time (370-250 BC). A community, often referred to as an ecological community, a biotic community, or biocoenosis, is a collection of populations that coexist and interact in a particular location for a period of time. For instance, the coexistence and interactions of numerous populations of trees, shrubs, herbs, grasses, animals, and microorganisms are reflected in a forest community. In other words, it is the aspect of the ecosystem that is biological as opposed to abiotic. A community was once supposed to function as a single thing, leading to the interpretation that it was a super organism. A different perspective, in contrast, saw a community as a collection of species, each of which has its own identity.

Every community has physical borders. Communities may be separated by boundaries

that are sharp. However, the intensity of sharpness varies, such as the barrier between a forest and a lake, or a forest and a grassland community. There is frequently an Ecotone, or transitional area, between two communities where species from both nearby communities can be found. The edge effect has made the ecological communities rich in species diversity (contrasting environmental conditions at the boundaries or the edges supporting a high species richness). An area of land between two forest communities, for instance, will feature plants and animals that are typical of both forest communities.

Characteristics of Communities

Communities can have a variety of traits, including species diversity, organisational structure, trophic structure, composition, dominance, succession, and developmental history. The following is a discussion of each of these.

Species diversity: Taxonomically diverse species constitute each community. The amount of distinct species in the community, including both common and unusual species, is referred to as species diversity. In contrast to physically or human-controlled ecosystems, species diversity is quite low in natural communities like tropical rain forests or coral reefs in oceans. The two elements of species diversity are species richness and species evenness. Species richness can be defined as the variety of species present and their relative abundance. In a technical sense, it relates to the proportion of species (S) to all species (N). A metric used to determine how evenly distributed species are in terms of numbers is known as species evenness. It refers to the distribution of each species within a community. For instance, a community is evenly distributed, if it contains 10 species with 10 or 9 individuals per species, as opposed to 10 species, in which one species has 90 individuals and the other 9 species include only 10.

Different diversity indices, which are mathematical expressions based on data on species abundance, can be used to quantify species diversity. The variety of species can be counted separately, as species richness, evenness, or overall diversity. The Margalef index of richness, designated by R in the formulas in Box 1, calculates the diversity of species (1958). The evenness index (designated by Hill as E) can be used to assess the evenness of a species (1973). The Shannon–Wiener Index, also known as Shannon's index or simply the index of diversity (denoted by H'; as given by Shannon and Weaver, 1963), and the Index of dominance (or X), also known as Simpson's index, as given by Simpson (1949), can both be used to calculate the diversity of the species (See Box 1). While the index of dominance has an inverse relationship with species diversity, Shannon's index has a direct correlation with it. The formulas are provided for computing various species diversity indexes.

Richness Index	$R = \frac{S-1}{\log N}$	as per Margalef (1958)
Index of dominance	$\lambda = \sum_{i=1}^{S} (n./N)^2$	as per Simpson (1949)
Index of diversity	$H = -\sum_{i=1}^{S} n_i/N \ln n_i/N$	as per Shannon-Weaver (1963)
Evenness Index	$E = \frac{1/\lambda - 1}{e^{H+} - 1}$	as per Hill (1973)

Where, S-total number of species, N-total number of individuals of all the species in a given area, n_i = number of individuals of the ith species of the area.

Fig. 10.18 Important Formulae

A community needs both resilience and resistance to stay stable. A community's resilience is its capacity to bounce back from a disturbance or eviction. Contrarily, resistance is a community's capacity to fend against disruption (any event that modifies a community's structure) or relocation (shifting of the community to some other place). The fact that any change in one or a few species would be made up for by the other species is one of the reasons that species-rich complex communities have become stable. However, some other researchers have shown that a society becomes unstable as its complexity increases. Therefore, it is debatable whether a community's complexity results in stable or unstable circumstances. Ecologists have, however, been effective in establishing a link between competition and variety or stability. If there is intense competition, there will be little diversity since only those species will survive that can adapt to the challenging environment and resist it. On the other side, if there is no competition and there is little overlap in the needs of the species, there will be no fighting over resources and more species will be able to cohabit. If the resources for the life support system—food, air, water, space, and sunlight—are few and the needs of the species overlap, the struggle will be fierce.

Community Organisation and Makeup

Every community has a unique structure and make-up. For example, the rainforest community in the Silent Valley will be distinct from the one in Arunachal Pradesh. The dominant growth form of a community, such as trees in forests or grasses in grasslands, is frequently used to describe the community's structure. The community's structural layout is determined by how the various growth forms are arranged. The physical configuration of the elements within a community is also crucial. For instance, in a forest, some plants may prefer the shade and only grow in the understory, while others like emergent trees are adapted to harsh sun exposure.

However, certain plants may flourish in dry, stony locations, while others require superior soil moisture. Similar to this, in a pond

environment, the soil-dependent plants will stay around the pond's boundaries, while the free-floating species would blanket the water's surface. Zonation describes the way a community is spread out horizontally.

Life forms: Christen C. Raunkiaer, a Danish botanist, proposed the concept of life forms, also known as Raunkiaer's life forms or Botanical life forms. Raunkiaer says that it is crucial for a community to understand how a plant survives in challenging circumstances. He saw the criterion of persistent buds being protected from harmful conditions as a climatic adaptation of the plant. Raunkiaer's approach classified plants into different life forms depending on where their buds were during seasons with unfavourable conditions (too cold or too hot). Raunkiaer gave phanerophytes, chamaephytes, hemicryptophytes, cryptophytes, and therophytes as his top five categories of life.

1. **Phanerophytes (sometimes known as plants with visible buds, i,e., phaneros, visible; phytes, plants):** These are the plants whose buds are located on the tops of shoots, high up on the plant. These are either scale-free or completely nude. The prevalence of phanerophytes increases in tropical regions, while it decreases in temperate and polar regions. Phanerophytes are further split into four types based on the height of trees.
   - **a)** Mega-phanerophytes are trees that are taller than 30 metres.
   - **b)** Meso-phanerophytes are trees between 8 and 30 metres in height.
   - **c)** Micro-phanerophytes are trees between 2 and 8 metres high.
   - **d)** Shrubs that are taller than 25 cm but less than 2 metres are known as nano-phanerophytes.
2. **Chamaephytes:** These are plants with buds that are either very close to the ground or reach a maximum height of 25 cm. In colder climates at higher altitudes or latitudes, such as temperate America, these plants can be found. The aerial parts of chamaephytes can perish throughout the growing season and conceal the buds. Fresh growth begins as soon as a favourable season arrives.
3. **Hemicryptophytes:** These are also found in cold climates where buds are shielded from the elements by remaining above ground but not deeply rooted. These include herbs that are annual or biannual (have a life cycle that lasts one year or one season and two years or two seasons, respectively).
4. **Geophytes:** These are also referred to as cryptophytes. The buds of these plants, which include bulbs and rhizomes, continue to be buried in the ground. These plants are primarily found in the world's dry regions.
5. **Therophytes:** These are ephemeral or seasonal plants. When the conditions are favourable, go through their entire life cycle swiftly and when those conditions are not favourable, they persist as seeds.

Raunkiaer also classified epiphytes, or plants that grow on or are attached to other plants, as a distinct category of life form, in addition to these five main groups. He classified cryptophytes into three subtypes—halophytes, hydrophytes, and geophytes, which are aquatic plants that are immersed or floating in water and have subterranean or perennating buds (plants in marshy swampy areas with high salt concentrations).

Environmental Succession

Due to variations in climatic and physiographic conditions and the actions of species and groups themselves, the environment is constantly changing over time. These influences cause noticeable changes in the community's dominants, which are eventually replaced by a new community in the same location. The process keeps going, and succeeding communities grow one after the other in the same area, until the last community once more stabilises for a while. Ecological succession is the occurrence of generally distinct sequences of communities over time in the same region.

With time and space, plant communities are always evolving. Communities might be experiencing these changes as a result of their own internal dynamics or shifting environmental situations. As a result, in a region, one community may displace another, which may then

be replaced by another community. Ecological succession refers to the gradual change in a community's structure and make-up over time, leading to the establishment of a stable community. Some ecologists refer to ecological succession as ecosystem development. It is a systematic and predictable process. The final stable community that is created at the conclusion of succession lasts a long time and coexists peacefully with the surrounding environment. The communities that appear for a brief period of time and are replaced one after the other are referred to as seral communities or seral stages. This final stable community is known as the climax community. The first plant community to settle in a region is known as a pioneer community, and the plants that make this community are known as pioneers or primary colonisers.

Succession Processes

Primary and secondary succession: A succession is referred to as primary, if it begins with the primary substrate, which is devoid of any living being or organic substances (an uninhabited environment). It is a slow-moving ecosystem that can exist in terrestrial or aquatic settings. In contrast, secondary succession begins from a substratum that has already been developed. In such locations, disturbances like rapid climate changes, fires, floods, or some biotic interference cause the plant community that had previously inhabited the area to change. Secondary succession is the word used to describe the relatively quick succession that begins from such a substratum.

Autogenic and allogenic succession: During the process of succession, the environment is changed by the mutual interactions of the living members of the community. The existing community is forced to be replaced as a result of these changes making the environment unfavourable for it. Such modifications might, however, be beneficial for another community. Autogenic succession is the process, wherein a community is replaced by factors that the community itself has generated. Allogenic succession is used to describe a succession in which the replacement of one community by another may be influenced by environmental causes rather than by living things.

Heterotrophic and autotrophic successions: An autotrophic succession is one in which green plants or autotrophs predominate so that there is a constant flow of energy throughout the entire process. Contrarily, heterotrophic succession is characterised by the dominance of heterotrophs like bacteria, fungus, actinomycetes, or even animals and a persistent drop in the energy flow.

Additionally, it might be one of the following varieties depending on the environment (mainly the moisture conditions) at the start of succession:

Hydrarch or hydrosere: If the succession starts from a water body, it is referred to as a 'hydrarch' or 'hydrosere'. A lake, pond, stream, bog, or even a swampy area could represent the water body.

Xerosere or xerarch: In this instance, the succession starts from dry, low-moisture environments like a desert, sand dunes, and boulders. Lithosere is the name given to a succession that specifically begins in rocky terrain, whereas psammosere is the name given to a succession that specifically begins in sand dunes.

Mesosere or mesarch: The succession is referred to as mesosere or mesarch if it begins in an area with suitable temperature and moisture conditions.

Halosere: It is a type of succession that develops in salty environments, or in places where the substratum has a high concentration of salt.

Community Structure

The phrase 'community structure' refers to a broad category of phenomena that emerge from the creation of ecological communities.

Community structure is a term used frequently in ecology to describe the boundaries that species interactions place on which different species can coexist. These restrictions on coexistence are known as assembly rules, and they can be used to limit the coexistence of both individual species and groups of species, such as the guilds described below. The part that competition has played in community structuring has been of special concern to ecologists. The following section will go into

further detail about this. The term 'community structure' is sometimes used to refer to how species are physically arranged within a community, such as how trees, bushes, and ground-dwelling herbaceous (non-woody) plants are arranged vertically in a forest.

Energy Flows in Food Webs: An Introduction

We are all aware that the largest and toughest predators, such as tigers and great white sharks, are relatively uncommon on Earth in comparison to other species. Do you realise why? In the early days of discovery in the new field of animal ecology, a scientist by the name of Charles Elton took the common knowledge that 'big fish eat little fish' and turned it into an organising principle that is still in use today—that plants and animals are organised into trophic or 'feeding' chains and food webs of interaction. He also established the concept of a pyramid of creature numbers, where, for instance, there are many plants at the base of the food web, fewer herbivores that graze on those plants, and even fewer predators that devour the herbivores. Thus, Elton observed the world around and concluded that large, fierce creatures were uncommon, but he did not know why. The 'mechanism' or reason for the scarcity of top predators in food webs eluded him. We will discover this process and answer the posed question by studying the nature of the energy flow in ecosystems. As energy travels through ecosystems, it is used and lost as heat, while new energy is continuously provided to the Earth in the form of solar radiation. The Earth is an open system in terms of energy, but a closed system in terms of elements such as nutrients that are continuously recirculated within and across ecosystems.

Energy and materials are vital to the structure, function, and composition of an ecosystem. The fundamental concepts of nutrition cycles have previously been introduced; this section will focus on energy. In terms of carbon cycling, note that 'materials' and energy can be inter converted. For instance, we know how many calories (a unit of energy) a gram of carbon compounds such as lipids or carbs have.

Autotrophs versus Heterotrophs

As a brief review, we acknowledge that certain species may synthesise organic compounds from inorganic substrates and store biochemical energy in the process. These are referred to as autotrophs, which means 'self-feeding'. Autotrophs are also known as primary producers. Plants, some protists, and some bacteria are able to produce complex organic molecules from simple inorganic substances (water, CO_2, and nutrients). This is often accomplished by photosynthesis, which, as its name suggests, requires light. We should also discuss the pathway known as chemosynthesis for completeness. Certain producer organisms, primarily specialised bacteria, can transform inorganic resources into organic chemicals in the absence of sunlight. There are numerous chemosynthetic bacteria in marine and freshwater ecosystems, especially those rich in sulphur or hydrogen sulphide gas. Chemosynthetic creatures, including chlorophyll-containing plants and other species capable of photosynthesis are autotrophs.

Numerous creatures can only acquire energy from other organisms. They are known as heterotrophs. They include consumers of all forms of organisms, including plants, animals, bacteria, and even decomposing tissue. Heterotrophs are also known as consumers.

The Primary Production

The phrase 'production' often refers to the development of new organic matter. When a wheat crop grows, photosynthesis creates new organic matter by converting light energy into energy stored in chemical bonds within plant tissue. This energy fuels the plant's metabolic mechanism. Over time, the plant synthesises new substances and structures, the cells divide, and the plant expands in size. Plants require light, carbon dioxide, water, and nutrients, and through photosynthesis, they make reduced carbon compounds and oxygen.

Whether one analyses the rate at which photosynthesis occurs or the rate at which an individual plant grows in size, primary production is the focus (The synthesis and storage of organic molecules during the growth and reproduction of photosynthetic organisms). The fundamental concept is that new chemical molecules and plant tissues are generated. Primary production results in the addition of new plant biomass to the ecosystem through time. Consumers obtain their energy either directly (herbivores, certain detritivores) or indirectly (from secondary producers) from primary producers (predators, other detritivores).

Is there a limit to the Maximum Primary Production? Yes is the quick answer. Let's take a quick look at the amount of energy captured by autotrophs and the efficiency of photosynthesis. Recall that the strength of solar radiation reaching the Earth's surface varies in part on the location: The equator receives the most energy, while the intensity diminishes as we approach the poles. As we learned in the lesson on ecosystems, these differences have significant effects on climate and result in the observed biome distribution patterns.

In addition, we know that just a small portion of the sun's radiation is utilised by the photosynthetic response in plants at the surface of the Earth. About half of the total solar radiation striking the Earth's outer atmosphere is reflected back to space by ice, snow, oceans, or deserts, or absorbed by gases in the atmosphere, for instance, the atmosphere's ozone gas layer absorbs nearly all ultraviolet rays, which accounts for about 9 per cent of the Sun's radiation.

Only about half of the rays that reach the Earth's surface is in the wavelength range that plants can use for photosynthesis (400-700 nm). This is known as Photosynthetically Active Radiation or PAR. Plants greatly absorb light of blue and red wavelengths, as well as light in the far infrared range (thus their green hue, the result of reflection of green wavelengths) and also reflect light in the near infrared region. Even if the correct wavelength is used, photosynthesis does not convert all of the light energy into carbon. Some of the light does not reach the leaf chloroplasts, where photosynthesis reactions take place, and much of the energy from light that is converted by photosynthesis to carbon compounds is used to maintain the plant's biochemical 'machinery', this loss is commonly referred to as 'respiration,' although it also includes thermodynamic losses. Therefore, plants do not utilise all of the potentially available light energy.

*** Gross Primary Production, GPP, is the total amount CO_2 that is fixed by the plant in photosynthesis.**

*** Respiration, R, is the amount of CO_2 that is lost from an organism or system from metabolic activity. Respiration can be further divided into components that reflect source of the CO_2**

R_p = Respiration by Plants

R_h = Respiration by Heterotrophs

R_d = Respiration by Decomposers (the microbes)

*** Net Primary Production, NPP , is the net amount of primary production after the costs of plant respiration are included. Therefore, NPP = GPP - R**

*** Net Ecosystem Production, NEP , is the net amount of primary production after the costs of respiration by plants, hetertrophs, and decomposers are all included. Therefore, NEP = GPP - (R_p + R_h + R_d)**

Fig. 10.19 Key Formulas

Evaluation of Primary Production

Due to the simplicity of the basic technique, the primary production of the world's oceans has been meticulously mapped, and numerous freshwater lakes have also been explored. Half of a series of miniature glass bottles with stoppers are wrapped with a substance such as tin foil to prevent light from penetrating. These are respectively known as the 'bright' and 'dark' bottles.

The bottles are filled with water from a certain location and depth; this water contains the aquatic ecosystem's microscopic plants and creatures. The bottles are sealed with stoppers to prevent the interchange of gases or organisms with the surrounding water and are then suspended at the same depth for a few hours. Inside the bottles, CO_2 is consumed and O_2 is created and the change in either of these gases over time can be measured.

Using chemical titration, for instance, the amount of oxygen dissolved in water can be easily quantified. Before suspending the bottles, the initial O_2 concentration is measured and expressed in milligrams of oxygen per litre of water (mg/L). After a scheduled incubation period, the final value is measured in both the light and dark bottles. What actions are occurring in each bottle that may affect the initial O_2 and CO_2 concentrations? The following equations describe them.

Light bottle: Photosynthesis or gross primary production (GPP) and respiration occur in the light bottle (R). As we observed previously, the difference between these two processes is Net primary production = NPP = (GPP - R)

Dark bottle: There is no photosynthesis and solely respiration in the dark bottle. (In this example, there may also be some consumer respiration in both bottles, unless a net was employed to remove heterotrophs.)

Consider the following simple illustration. It demonstrates how we account for changes in the original oxygen concentrations in water that happened during incubation. We will assume that our incubation period lasted one hour. Oxygen concentrations measured:

First bottle = 8 mg O_2/L; second bottle = 10 mg O_2/L; third bottle = 5 mg O_2/L

Due to photosynthesis, the amount of oxygen in the light bottle rose relative to the starting amount, whereas the amount of oxygen in the dark bottle decreased. With this information, we can calculate our system's respiration, NPP, and GPP:

(Initial - Light) = (10 - 8) = 2 mg/L/h

= (GPP - R) = NPP

(8 - 5) = 3 mg/L/h = Respiration

(Light - Dark) = (10 - 5)

= 5 mg/L/hr = (NPP + R) = GPP

Thus, we have a measurement of our system's net and gross primary output, as well as, its respiration. When primary output is very low, the oxygen approach has its limitations. C14 ($^{14}CO_2$), a radioactive form of carbon, can be used to monitor carbon intake and fixation in certain instances. In order to convert the results between the oxygen and carbon approaches, multiply the oxygen values by 0.37 (The factor comes from differences in atomic mass).

'Biological diversity' is defined as the variety of all life forms, including various plants, animals, and microorganisms, as well as, the genes and ecosystems they generate.

The definition encompasses not just species variety but also genetic diversity of individual organisms, habitat diversity, natural community diversity, and ecological process diversity throughout the biosphere.

Food Chains

It is an organismal chain through which nutrients and energy pass—from producer to the main consumer, then to the secondary consumer, followed by tertiary consumer to quaternary consumer to detritus feeder. It is the general order of the food chain. Herbivores are the main consumers. Everyone else is either a meat eater (carnivore) or both (omnivores). A typical food chain in a field ecosystem might look like this:

grass → grasshopper → mouse → snake → hawk

Detritus vs grazing food chains: Detritus food chains are based on detritivores (which

break down detritus and wastes), whereas grazing food chains are based on producers (photosynthesis). While detritus chains are significant in forest litter, grazing food chains are significant in marine and aquatic environments.

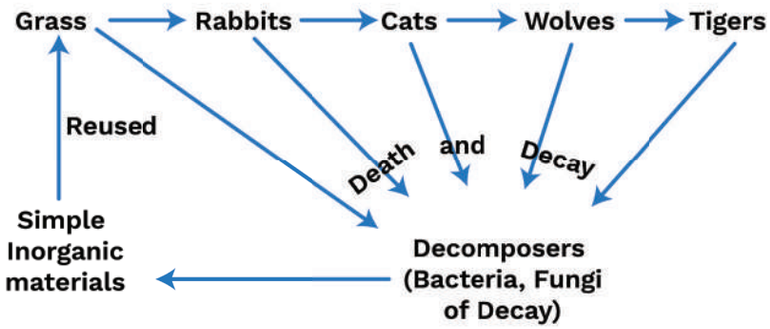

Fig. 10.20 Food Chain

Food Web

Of course, the real world is more intricate than a straightforward food chain. Food webs are made up of connected food chains rather than discrete food chains. The food chain and ecosystem are more stable the more alternate avenues there are for energy to pass through. Since there are producers at the bottom of the food webs you can see, which the herbivores subsequently graze on, these are grazing food chains. Although grazing food networks are significant, detritus-based food chains exceed them in nature. The decomposers at the bottom of the food chain in detritus-based food chains support the predators that consume them. In many ecosystems, debris contributes a greater portion of an animal's weight (or biomass) than living producers do.

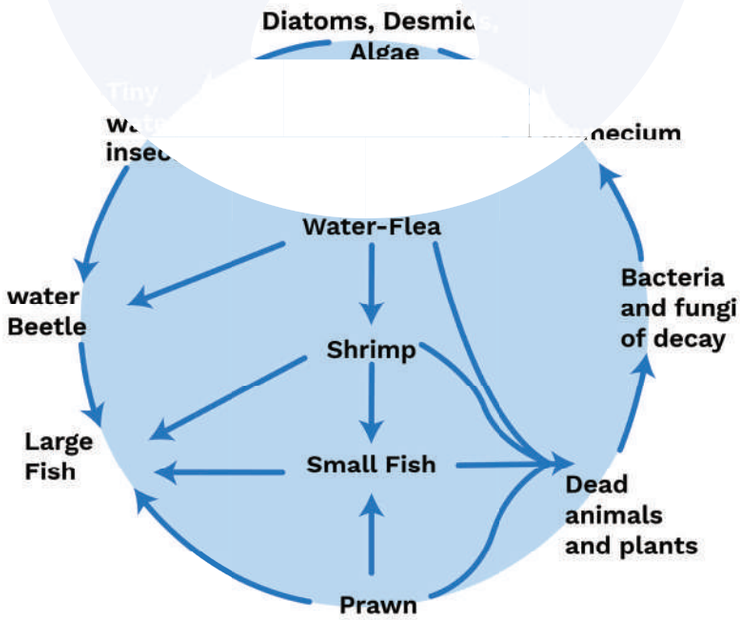

Fig. 10.21 Food Web

The energy flow brought on by solar radiation's influences two occurrences that are closely related to one another and have their roots in the Earth's surface. It initially allows plant cells to come in contact with dissolved minerals in lakes, oceans, or saline soil solutions. This naturally results in cellular assimilation. The energy input required by chlorophyll to create organic matter—and subsequently living matter—is then ensured.

Only 1.2 per cent of the sunlight that reaches plants is actually absorbed, and roughly one-third of that energy is converted into chemical molecules that other organisms might consume. The plant's biomass is made of these organic components. About 10 per cent of eaten biomass can be converted into biomass by organisms at higher trophic levels. A herbivore may therefore gain 1 kilogram of weight after consuming 10 kg of plant material.

$$\textbf{Productivity} = \frac{\textbf{mg of C/m}^3\textbf{/h}}{\textbf{mg of C/m}^3}$$

Primary Manufacturing

Primary production describes the pace at which a specific amount of organic matter is created from mineral matter and energy in a particular amount of time. It is measured as mass of carbon assimilated per interval of time. Autotrophs, also known as primary producers, are the first trophic level or link in what is often referred to as the food chain and are responsible for primary production. Plants that produce their own matter through photosynthesis—and consequently from photons—are the most well-known autotrophs. Additionally, there are autotrophic microbes that use chemical reactions to provide energy for production. These are referred to as chemosynthetic creatures or chemoautotrophs.

Efficiency

The majority of authors use the wrong definition of productivity, which is the amount of biomass generated per unit of surface area over a specific period of time, or annual net primary production. Actually, the ratio of production to habitat biomass at any particular time serves as a measure of productivity.

Efficiency = P/B

It is represented with a unit that is opposite to time (t-1).

Productivity is represented as follows for plankton in an aquatic environment where the primary production is calculated in milligrams of carbon assimilated per cubic metre of water per hour. The rate of biomass renewal, or turnover, is its inverse.

Renewal Rate = B/P

The plankton renewal rate in the above case is: mg of C/m^3 mg of C/m^3/h is the rate of renewal. Plankton are extremely productive. Cells can divide in a day when the conditions are right. Therefore, their renewal rate is one day every year. For terrestrial plants, this turnover varies by organ and plant and is substantially lower. Thus, for leaves, it is 1.1 each year, while for wood, it is 0.02 per year.

Transfer of Energy and Matter

For a trophic level, energy efficiency is defined as the ratio of energy released to energy consumed, or, more specifically, as the ratio of energy fixed to energy received.

Efficiency of consumption: The consumption efficiency is the ratio of the energy that a consumer integrates to energy that is present in the field at hand. This will be the portion of a prey's energy that the predator can efficiently incorporate. Not all of the consumer-accessible net production is utilised. The entire net productivity of a plant is not consumed by a herbivore. For instance, it prefers sensitive shoots and discards roots and woody branches. The bones and shells that a carnivore leaves behind are filled with energy. The efficiency of consumption varies greatly depending on the ecology.

Efficiency of assimilation: As food travels through the digestive tract, it undergoes both mechanical and chemical digestion processes. Only a portion of the food, the nutrients, enters

the bloodstream through the intestinal mucous. The remainder is not absorbed and is expelled with the faeces. The energy assimilated (A) by nutrients and energy E (assimilation) = A/I constitute the assimilation efficiency.

Depending on the types of consumer organisms, it varies a lot. The phytoplankton thrives in the aquatic environment when there are significant inputs of mineral components like nitrogen and phosphorus, and this growth is referred to as 'bloom' or 'flowering of water'. Under these circumstances, the integrating filtering zooplankton consumes far more organic matter than is necessary for its metabolism.

A significant portion of the food consumed is released as faeces, which settle in the deeper zones and are eaten by other creatures. Since a significant portion of these faeces contains phytoplanktonic cells, which are not killed by the zooplankton's digestive enzymes, the growth is aided by nitrogen and phosphorus released during the enzymatic activities. The biomass of the consumer does not increase as a result of anything that is ingested. Because it is needed to meet the metabolic requirements of respiration, excretion, or homeothermy, a sizeable portion of the energy taken in is not fixed. This allows us to define another type of yield, the net production efficiency, which corresponds to the ratio of fixed energy, i.e., net energy (N) over assimilated energy (A): E (net production) is equal to 0.

Ecological efficiency: Because it gauges a trophic relation's yield, ecological efficiency is the most pertinent to our discussion. It is also known as ecological growth yield, feed efficiency, or ecological yield. It is the sole ratio that captures the energy losses incurred as feed levels are changed. As a result, it has a considerable benefit when trying to comprehend how biocenoses work. It is described as the proportion of energy ingested (I) found in the feed consumed to energy fixed (N) in the net production of a consumer.

E (environmental) = N/I

Ecological efficiency, for instance, is the ratio between a predator's net production and the net production of its prey. It has to do with the ratio of energy values, not of matter weights.

The Various Degrees of Diversity

The term 'diversity' is most frequently used to describe species diversity, which is a measurement of number of species and their relative abundances within a community. Despite the fact that the species is the taxonomic level that is most frequently employed, research at bio-geographical scales also assesses the diversity of genera (generic diversity) or families to compare regions. A similar metric known as genetic diversity assesses a variety of genotypes found within a species or population. Through the selection of crop plant types and domestic animals, humans have long been aware of the concept of genetic diversity. The term 'landscape diversity' has only lately been created to describe a variety of communities (or vegetation kinds) that exist at the size of the landscape.

Genetic Diversity

Genotype variety within a population or species is referred to as genetic diversity. The phrase might refer to a specific quality (e.g., the colour of corn grains, resistance to disease). In a broader sense, it refers to the entire degree of diversity for all qualities.

Subspecies are populations that seem to be genetically distinct from other populations of the same species (a geographically recognisable population). Races and varieties are terms for human-modified genotypes with reference to animals. In fact, the idea has long been used in agriculture and animal breeding, where breeders have created new kinds by exploiting the natural genetic varieties of wild parents and relatives of cultivated species.

Techniques for Calculating Genetic Diversity

Study of morphology: If a trait has a simple genetic determinism (i.e., it is determined by one

or a few genes), it is feasible to analyse genetic variety by merely counting the frequency of the various phenotypes present in the population. Polymorphism is the presence of two or more phenotypes in a population.

The variety of distinct protein forms within a population can be determined using the chemical technique of electrophoresis. Measuring the variation in these proteins indirectly gauges the genetic diversity because the various forms are a direct result of the variation in the underlying genetic code.

Sequencing techniques: Molecular biological technologies have recently been developed to delve directly into the DNA composition. Genetic diversity may be measured because of individual variation in the DNA make-up.

What makes genetic variety crucial?

A population's genetic variety is a key factor in determining how adaptable it is to environmental change, unintentional population declines, and attacks from adversaries like illness. Genetic diversity can be thought of as a species' 'life insurance' against these threats. Without such variation, natural selection cannot work and extinction may ensue from environmental changes if those in the population who can adapt to them are not present.

Diversity of Species

Indices of Diversity

If you want to compare communities or regions, using a standard measure of diversity is needed. A diversity index is a straightforward number that may be used to summarise the data in a list of species and their abundances. There are several of these indices. The total number of species in a community is the simplest index to use. This is typically denoted by the symbol s and is known as species richness (or sometimes n). The drawback of species richness is that species abundances are not taken into account. There are two widely used indices that consider species abundances.

$D = 1/d^2$ Simpson diversity index

$H = -(p_i \ln p_i)$ Shannon diversity index

Where pi is each species' relative abundance. It will allow you to observe the results of including abundance. It should be noted that these indices take into account both variations in abundance and richness. In order to determine how equally the species are distributed, we may only wish to take into account the relative abundances of the species, rather than the species richness. In order to do this, D or H can be expressed as a per centage of the value that would be anticipated if all species were present in equal abundance.

Simply divide D by the species richness(s) and H by the logarithm of s to accomplish this. In example, observe that community 1 is significantly more diversified (D = 5.0 cf. 1.06, H = 1.61 cf. 0.21) while having the same number of species (s = 5) as community. Also, observe that communities 1 and 3 have the same level of evenness (D/s = 1, H/ln(s) = 1) while having differing numbers of species.

Diversity Indicators at Several Spatial Scales

Diverse geographical scales are acknowledged when diversity is taken into account. The diversity found in a community sample is referred to as alpha diversity. The diversity among community samples is referred to as beta diversity.

Since we are aware that various species can frequently be found in various settings, explaining beta diversity normally presents little difficulty. In contrast, it can be quite challenging to explain alpha diversity. Hutchinson (1961) posed the 'paradox of the plankton' which is one of the most well-known discussions of alpha diversity, in which he questioned how so many phytoplankton species could persist when they all share the same environment and fight for the same basic resources (e.g., light and nutrients).

Gamma-diversity, or the fusion of alpha and beta diversity, is diversity at the regional level. The diversity of species fluctuates over time as well.

Important Terms Related to Biological Diversity

Diversity: Totality of the species, genes, and ecosystems in a given area.

Genetic diversity: It refers to gene variety within a species.

Ecological diversity: Variation in a given area's habitats, community types, and abiotic environment.

In-situ conservation: Keeping an organism in its natural environment is known as in-situ conservation.

Ex-situ conservation: It includes cryopreservation, tissue culture, and the preservation of organisms in botanical gardens, zoological parks, and sanctuaries.

Hot spot: Priority conservation regions that are both highly species-rich and imperilled by extinction.

Exotic or alien species: These are animals or plants that have been brought into an ecosystem from elsewhere.

Biosphere reserves: These are safeguarded coastal or inland environments with distinctive biodiversity.

Sacred forest/sacred groves: These are forest swaths that tribal communities guard because of their religious convictions.

Biomaterial is stored at extremely low temperatures using cryopreservation.

Red List guide: The IUCN issued the book, which includes a list of species that are recognised to be endangered.

- Program on Man and Biodiversity (MAB)
- The World Wildlife Fund for the environment
- Indian Board for Wildlife (IBWL)
- **Biological Program:** International
- International Union for the Conservation of Nature and Natural Resources (IUCN)
- United Nations Development Program, or UNDP

Biogeochemical Cycles

Through the numerous transfers between trophic levels, energy enters ecosystems as sunlight (or inorganic compounds for chemoautotrophs) and exits as heat. The material that makes living things is preserved and recycled, nevertheless. Carbon, nitrogen, hydrogen, oxygen, phosphorus, and sulphur are the six most frequent elements linked to organic molecules. They can persist for extended periods of time in the atmosphere, on land, in water, or below the surface of the Earth in a variety of chemical forms. This material recycling is influenced by a number of geologic processes, including weathering, erosion, water drainage, and the subduction of continental plates. A biogeochemical cycle is the term used to describe the recycling of inorganic matter between living organisms and their environment. Geology and chemistry play significant roles in the study of this process.

Hydrogen and oxygen, both of which are necessary for all biological processes, are found in water. The hydrosphere is the region of the Earth where water is stored and moved. This water can be in the form of liquid on the surface and below it, frozen (rivers, lakes, seas, groundwater, polar ice caps, and glaciers), or it might be in the form of water vapour in the atmosphere. All organic macromolecules contain carbon, which is also a crucial component of fossil fuels. Our nucleic acids and proteins include a significant amount of nitrogen, which is also essential for human agriculture. One of the key components of artificial fertilisers used in agriculture and their accompanying environmental effects on our surface water is phosphorus, which, along with nitrogen, is a major component of nucleic acid. When fossil fuels like coal are burned, sulphur is released into the environment. Sulphur is essential for the 3-D folding of proteins (such as in disulfide binding).

These elements' cycles are intertwined. For instance, the leaching of nitrogen and phosphate into rivers, lakes, and seas depends on the flow of water. In addition, the ocean itself serves as a significant carbon sink. Mineral nutrients are thus cycled, either quickly or slowly, between the biotic and abiotic worlds, from one living thing to the next.

The Hydrologic Cycle of Water

The foundation of all biological activities is water. Human cells contain more than 70 per cent water, and the human body is more than half water. So, to survive, the majority of terrestrial animals require access to freshwater. However, 97.5 per cent of the water reserves on Earth are saline water, which cannot be used

for drinking. About 99 per cent of the remaining water is frozen or kept underground as water. Therefore, only 1 per cent of fresh water may be conveniently accessed from lakes and rivers. The tiny amount of fresh surface water supply is crucial for the survival of several living creatures, including plants, animals, and fungus, and its absence can have a significant impact on ecosystem dynamics. Of course, humans have created technology to improve the availability of water, such as drilling wells to gather groundwater, collecting rainwater, and desalinating ocean water to produce potable water. The availability of fresh water is still a significant problem in contemporary times, despite the fact that this pursuit of drinkable water has been ongoing throughout human history.

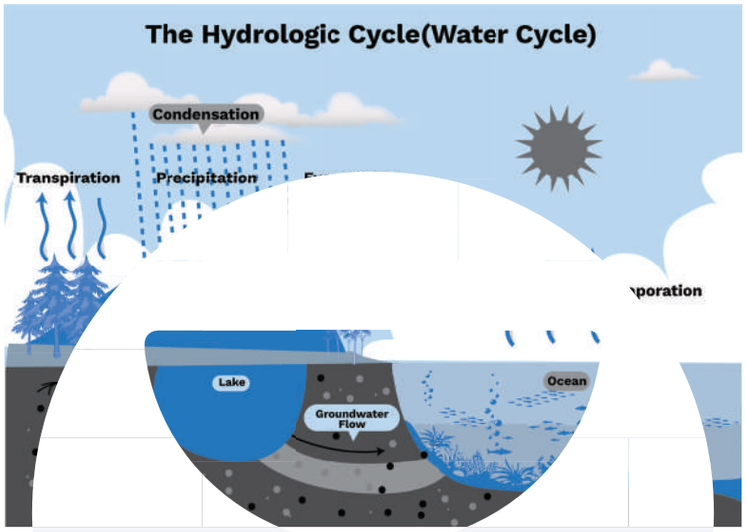

Fig. 10.22 Water Cycle

The dynamics of ecosystems depend a lot on the water cycle. Climate and by extension, the habitats of ecosystems, some of which are found in remote regions of the Earth are significantly influenced by water. The majority of the water on Earth is permanently trapped in ice, underground, and in the oceans. The following are some of these procedures:

- Evaporation/sublimation
- Condensation/precipitation
- Movement of subsurface water
- Snowmelt and surface runoff
- Streamflow

The Cycle of Carbon

In living things, carbon is the second most common element. Since carbon is a component of every organic molecule, living things place a high value on its function in the formation of macromolecules. Those originating from fossilised organisms, primarily plants, which humans use as fuel, carbon compounds have a particularly high energy content. There are now more nations than ever before that consume enormous amounts of fossil fuels. Global demand for the finite supply of fossil fuels on Earth has increased since the start of the Industrial Revolution, which has led to an increase in the amount of carbon dioxide in our atmosphere. This rise in carbon dioxide is a serious environmental concern across the globe since it has been linked to climate change and other disruptions of the Earth's ecosystems. As a result, the 'carbon footprint' is determined by the amount of carbon dioxide produced and the consumption of fossil fuels by various nations. It is easiest to study the carbon cycle as two interconnected sub-cycles. One that deals with the quick exchange of carbon among living things, and the other that deals with the slow cycling of carbon through geologic processes.

Carbon moves through the air, water, and soil in a complex manner that frequently happens much more slowly geologically than it does between living things. In what are referred to as carbon reservoirs, which include the atmosphere, liquid water bodies (primarily oceans), ocean sediment, soil, terrestrial deposits (including fossil fuels), and the Earth's interior, where carbon is retained for protracted periods.

As previously mentioned, the atmosphere serves as a significant carbon dioxide storehouse. Carbon dioxide is crucial for photosynthesis. The oceanic carbon reservoir has a significant impact on the amount of carbon dioxide in the atmosphere. The amount of carbon found in each place is influenced by the circulation of carbon between the atmosphere and water reservoirs, and each has a reciprocal impact on the other. When atmospheric carbon dioxide (CO_2) is dissolved in water, it reacts with water molecules to generate carbonic acid, which subsequently ionises to form carbonate and bicarbonate ions.

Step 1: CO_2 (atmospheric) $\rightleftharpoons$ CO_2(dissolved)
Step 2: CO_2 (dissolved) + H_2O $\rightleftharpoons$ H_2CO_3(Carbonic acid)
Step 3: H_2CO_3 $\rightleftharpoons$ H^+ + HCO_3^- (bicarbonate ion)
Step 4: HCO_3^- $\rightleftharpoons$ H^+ + CO_3^{2-} (carbonate ion)

Fig. 10.23 Carbon Cycle Steps

Cycle of Nitrogen

It is challenging to introduce nitrogen into the living world. Even though this molecule makes up around 78% of the atmosphere, plants and phytoplankton are not able to absorb nitrogen from it (which exists as firmly linked, triple covalent N_2). Free-living and symbiotic bacteria introduce nitrogen into the living world by nitrogen fixating it into their macromolecules (conversion of N_2). Most aquatic environments with sunlight support cyanobacteria, which are essential for nitrogen fixation. Cyanobacteria have the ability to fix nitrogen from inorganic sources. Legumes (including peas, beans, and peanuts) rely on *Rhizobium* bacteria, which coexist symbiotically in their root nodules and supply them with the organic nitrogen they require. *Azotobacter* is one of many free-living bacteria that fix nitrogen.

Since many ecosystem activities, including primary production and breakdown, are constrained by the supply of nitrogen, organic nitrogen is particularly crucial to the study of ecosystem dynamics.

In terrestrial systems, this process takes place in three stages: ammonification, nitrification, and denitrification. The first step in the ammonification process is when specific bacteria and fungi transform nitrogenous waste from live or dead animals into ammonium (NH_4^+). Second, nitrifying bacteria like *Nitrosomonas* use nitrification to change the ammonium into nitrites (NO_2). Similar organisms then transform nitrites into nitrates (NO_3). Thirdly, the nitrates are transformed into nitrogen gas by the process of denitrification, which is carried out by bacteria like *Pseudomonas* and *Clostridium*. This step enables the nitrates to once again enter the atmosphere.

The two main ways that human activity can release nitrogen into the environment are when fossil fuels are burned, which results in the release of various nitrogen oxides, and when artificial fertilisers are used in agriculture, which cause surface runoff to carry the fertilisers into lakes, streams, and rivers. Numerous effects of atmospheric nitrogen on Earth's ecosystems are linked to it, including the creation of acid rain (as nitric acid, HNO_3) and greenhouse gases (as nitrous oxide, N_2O), which may contribute to climate change. Freshwater and saltwater eutrophication, a process where nutrient runoff causes the excess development

of microorganisms, depletes dissolved oxygen levels, and kills ecosystem species, is one of the main effects of fertiliser runoff.

Similar activities take place in the marine nitrogen cycle, where marine microorganisms carry out the ammonification, nitrification, and denitrification processes. In geologic time, the uplift of the Earth's surface could have transported some of this nitrogen sediment from the ocean floor to land, where it must have been absorbed into the rocks on land. A recent study revealed that this mechanism may actually be significant and should be considered in any analysis of the global nitrogen cycle, despite the fact that it has generally been viewed as less important than nitrogen fixed from the atmosphere (Morford, Houlton, and Dahlgren, 2011).

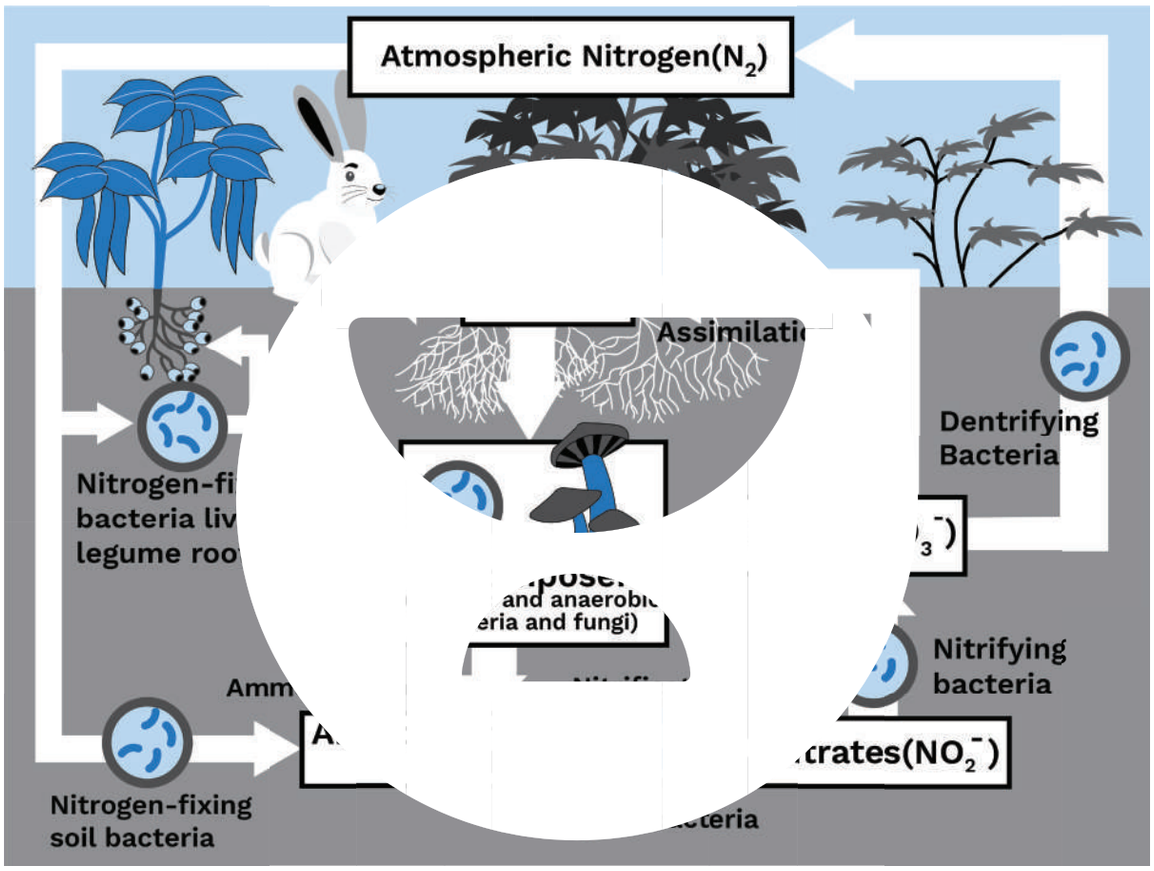

Fig. 10.24 Nitrogen Cycle

The Cycle of Phosphorus

Phosphorus is a nutrient that is necessary for all life processes. It is a key component of phospholipids and nucleic acids, and it also contributes to the structural elements of our bones (calcium phosphate). In aquatic environments, phosphorus is frequently the limiting nutrient (required for growth).

In nature, phosphorus is found as the phosphate ion (PO_4^{3-}). In addition to phosphate runoff brought on by human activity, phosphates are also released into rivers, lakes, and the ocean naturally as they are weathered from phosphate-containing rock. The ocean gave birth to this rock. The bodies of ocean animals and their excretions are the main sources of phosphate-containing ocean sediments. Volcanic ash, aerosols, and mineral dust, however, may potentially be important phosphate sources in isolated areas. As parts of the Earth's surface

are raised during geologic time, this silt is subsequently transported to land.

Additionally, phosphate that is dissolved in the water and marine ecosystems exchange phosphorus back and forth. The average phosphate ion has an oceanic residence time of between 20,000 and 100,000 years, and it moves from the ocean to the land and through the soil at a very sluggish rate.

The excessive proliferation of microbes and the depletion of dissolved oxygen caused by excess phosphorus and nitrogen that enters these ecosystems from fertiliser runoff and sewage causes the mortality of numerous ecosystem species, including shellfish and fish. Dead zones in lakes and at the mouths of many significant rivers are the result of this phenomenon.

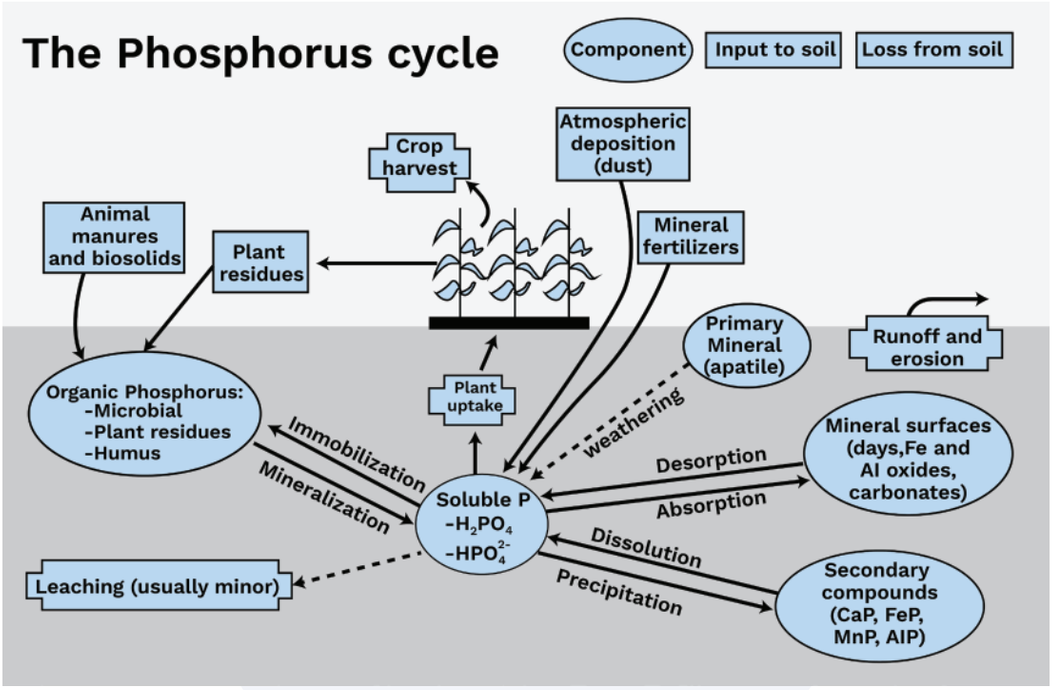

Fig. 10.25 Phosphate Cycle

The Cycle of Sulphur

Sulphur is a component that contributes to the creation of disulfide bonds inside proteins, which aid in determining the 3-D folding patterns of proteins and subsequently their functions. It is a component of the amino acid cysteine. Sulphur dioxide (SO_2), the atmospheric version of which is produced by the breakdown of organic molecules, enters the atmosphere through three different processes: volcanic eruptions, geothermal vents, and human combustion of fossil fuels.

Precipitation, direct fallout from the sky, rock weathering, and geothermal vents are the four main processes through which sulphur is deposited on land. Sulphur is present in the environment as sulphur dioxide (SO_2) and dissolves as weak sulphuric acid as rain falls through the atmosphere (H_2SO_4). In a process known as fallout, sulphur can also fall directly from the atmosphere. Additionally, sulphur is released into the soil during the weathering of sulphur-containing rocks. These rocks are made of ocean sediments that have been geologically elevated and transported to land. The sulphur from these soil sulphates (SO_4) can then be used by terrestrial ecosystems, which release the sulphur back into the atmosphere as hydrogen sulphide (H_2S) gas once the organisms die and decompose.

The global sulphur cycle's equilibrium has been significantly altered by human activity. Greater amounts of hydrogen sulphide gas are released into the atmosphere when huge amounts of fossil fuels, particularly coal, are burned. Acid rain is a phenomena that is created when raindrops pass through this gas. Acid rain is corrosive rain that harms aquatic habitats by converting rainfall into weak sulphuric acid as it falls to the ground through sulphur dioxide gas. Acid rain harms both the natural and built environments. It lowers the pH of lakes, which kills a lot of the local fauna, and causes buildings to deteriorate chemically. For instance, acid rain has over time caused considerable harm to numerous marble monuments, including the Lincoln Memorial in Washington, DC. These illustrations highlight the extensive impacts of human activity on the ecosystem as well as the obstacles we still face today.

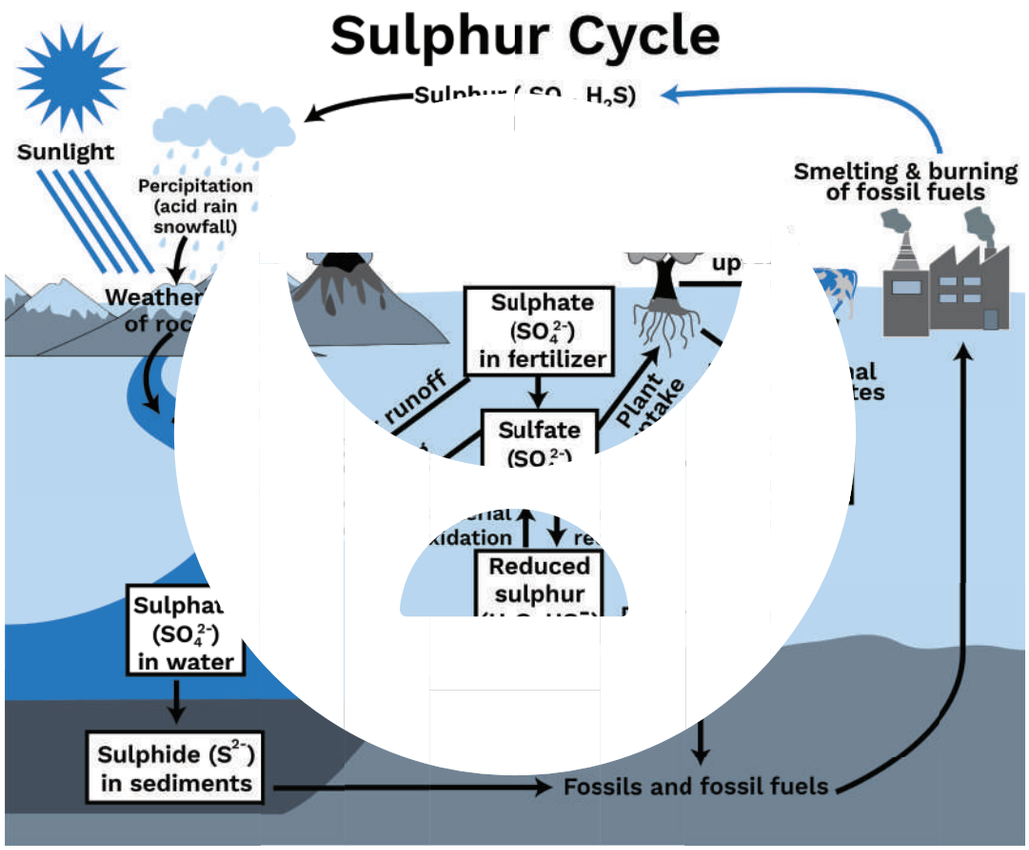

Fig. 10.25 Sulphur Cycle

Biogeographic Regions of the Earth

The field of research known as biogeography studies tries to explain how populations, species, and ecological communities are distributed over Earth.

Given that there are only a limited number of potential responses to the query of why a species is or is not present in a certain region, explaining species distributions may appear to be a straightforward task.

When a species is present in a given location, it either evolved there or it evolved elsewhere and diffused to the area. When a species is absent from the area, it either evolved elsewhere and never distributed to the area, or it was previously present but no longer resides there. Finding the correct response involves knowledge of the evolutionary histories of the various species, which can be learned from fossils and from understanding their phylogenetic

relationships. It also needs details on how the geology of Earth changed as the species evolved, including information on continental drift, glacial advances and retreats, changes in sea level, and mountain construction. Such geological knowledge can help us to determine whether species dispersed and colonised new places from a remote area of origin or whether they evolved where they are currently located. It is possible to divide the Earth into several significant biogeographic zones due to the differences in the biotas of the continents.

Based on the taxonomic similarity of the creatures that inhabit them, biogeographic areas are defined. Where species compositions drastically shift over short distances, biogeographic regions' borders are drawn.

An endemic species is one that can only be found in a certain area. Due to the significant immigration restrictions imposed by water barriers, isolated islands generally contain diverse endemic biotas. Allopatric speciation frequently creates distinct species and groups if the islands are big enough or are a part of an archipelago. For instance, Madagascar, a sizable island off the eastern coast of Africa, has almost entirely indigenous tracheophytes and vertebrates. Madagascar might be considered a biogeographic region in and of itself, but islands are regarded differently from continents because dozens of them would meet the criteria based on the distinctiveness of their biotas.

The majority of species are restricted to just one biogeographic area. The greatest egret, osprey, peregrine falcon, and barn owl are a few more species that may be found in every continent but not Antarctica. *Homo sapiens* is most likely the most common species today.

Terrain-Based Biomes

Ecologists distinguish between biogeographic areas and biomes, which are distinct ecosystem types depending on the composition of their main vegetation. Wherever on Earth, a biome is situated, its vegetation will look similar, yet despite their visual similarity, the plant species that make up these communities may not be closely linked in terms of evolution. Each biome comprises numerous species in all other taxonomic groupings, but they are named for and distinguished from one another by their distinctive flora, which is occasionally accompanied by a description of their location or climate.

High latitudes and high mountains are where you can find tundra. In all latitudes, the Arctic and high mountains are home to the tundra biome. Permafrost, or permanently frozen soil, lies beneath the short perennial plants that make the Arctic tundra vegetation. During the brief summers, when the sun shines continuously, the top few millimetres of soil melt. Lowland Arctic tundra is very wet despite minimal precipitation because water cannot drain through the permafrost. Plants only grow for a few months a year. The majority of Arctic tundra animals either migrate to the region just during the summer or spend most of the year dormant.

Boreal woodland can be found in temperate zone mountains at lower elevations and equatorward tundra. Boreal forest summers are brief, and winters are lengthy and extremely cold (although often warm). Evergreen trees benefit from the short summers since they can begin photosynthesizing as soon as the spring temperatures rise.

Evergreen coniferous gymnosperms make up the majority of the boreal forests in the Northern Hemisphere. The southern beech (Nothofagus), some of which are evergreen, is the most common tree in the southern hemisphere.

In both hemispheres, evergreen forests can be found growing along the west coastlines of continents at middle to high latitudes, when the summers are cool and dry and the winters are moderate but very wet. The tallest trees on Earth can be found in these forests. There are not many tree species in boreal woods. The dominating creatures, like moose and hares, consume leaves. Rodents and birds are supported by the seeds in pine cones.

Eastern North America, Eastern Asia, and Europe are all home to the temperate

deciduous woodland biome. In these areas, the temperature varies greatly from summer to winter. Throughout the year, precipitation is distributed very evenly.

The majority of the trees in these woods are deciduous, which shed their leaves in the chilly winters and develop leaves that quickly photosynthesise in the hot, humid summers. Compared to boreal forests, there are many other type of trees here. The temperate forests with the most species diversity can be found in Eastern China, Eastern Japan, and the Southern Appalachian Mountains of the United States—regions that did not experience glaciation during the Pleistocene. There are many genera of both animals and plants that are present in all three of the distinct deciduous forest biomes.

There are various locations around the world where the temperate grassland biome can be found, and they are all generally dry for most of the year. The majority of grasslands, including the Great Plains of North America, the veldt of South Africa, and the pampas of Argentina, experience hot summers and comparatively mild winters. This biome's majority has been turned over to agriculture. California grasslands receive most of their precipitation during winters, whilst other grasslands receive the majority of their precipitation during summers (Great Plains, Russian Steppe). Although grassland vegetation has a straightforward structural make-up, it is abundant in perennial grass, sedge, and forb species. When forbs are in bloom, grasslands can explode with colour. Plants in grasslands are suited to fire and grazing. After being burned or grazed, they quickly regenerate because they store a large portion of their energy underground.

High and arid deserts are cold. The cold desert biome can be found in dry areas at mid-latitudes and higher, particularly in the interiors of big continents under the rain shadows of mountain ranges. Temperature fluctuations throughout the seasons are wonderful.

Several low-growing shrub species predominate in cold deserts. In the winter, the soil's top layers are replenished with moisture, and in the spring, plant development is at its peak. The yearly primary yield is poor because the soils dry out quickly in the spring. Although most taxonomic groupings of species are somewhat under represented in cold deserts, this biome has a rich fauna of seed-eating birds, ants, and rodents because of its plants' propensity to generate vast quantities of seeds. Around 30° latitude, hot deserts begin to appear.

The two belts that make the hot desert biome are located at latitudes 30° north and 30° south and are where air falls, heats, and gathers moisture. The majority of the rain that falls on hot deserts occurs in the summer. However, storms that form over mid-latitude oceans can also bring rain in the winter. In the heart of Australia and the African Sahara Desert are the driest huge areas, where summer and winter rains seldom ever fall.

Hot deserts feature richer and more architecturally diversified vegetation than cold deserts, with the exception of these driest areas. In some hot deserts, succulent plants that retain a lot of water in their expanded stems are noticeable. Annual plants produce a large number of seeds that sprout when it rains. Animals frequently disperse fruit and perform pollination. The abundance of rodents, termites, and ants is frequently astounding, and the species diversity and abundance of lizards and snakes are usual.

The Chaparral Has a Dry Pleasant Climate

At moderate latitudes (about 30°), when mild ocean waters flow offshore, the chaparral biome can be found on the western flanks of continents. This biome experiences chilly, rainy winters and warm, dry summers. The Mediterranean region of Europe, Coastal California, Central Chile, extreme Southern Africa, and Southwestern Australia all have similar climates. Low-growing shrubs and trees with robust, evergreen leaves make the majority of the vegetation in chaparral. In the early spring, when insects are active and birds are laying their eggs, shrubs perform the majority of their growth and photosynthesis. Annual plants are widespread and produce a large number of seeds that land on the ground. As a result, this biome is home to enormous

numbers of tiny rodents, the majority of which deposit their seeds in underground burrows. The flora in the chaparral has evolved spontaneously to withstand recurrent fires. In the late fall, when a significant number of migrating birds arrive from the north, many bushes in chaparral in the Northern Hemisphere yield fruits that are spread by birds.

Savannas and Thorn Forests Have Comparable Climates

On the equatorial sides of scorching deserts, thorn woodlands grow. Semi-arid conditions prevail; winter months may see little or no precipitation, but summer months may see significant amounts. There are numerous plants in thorn forests that resemble those in scorching deserts. Small trees and prickly shrubs, many of which lose their leaves during the long, dry winter, make the majority of the vegetation. Acacia species are widespread in thorn woodlands all over the world. Africa, South America, and Australia all feature sizable areas of savannas, which are vast fields of grasses and grass-like plants with a few scattered trees.

The greatest savannas are found in Central and Eastern Africa, where the biome is home to numerous large carnivores that feed on grazing and browsing mammals, as well as, a significant population of these animals themselves. The savannas are kept up by the browsers and grazers. Savanna vegetation usually turns back into a dense thorn forest if it is not grazed, browsed, or burned.

In Heated Lowlands, Tropical Deciduous Woods Can Be Found

Tropical deciduous woods replace thorn forests as the length of the rainy season lengthens toward the equator. These forests are far more diverse in terms of plant and animal diversity than thorn forests, with larger trees and less succulent plants.

During the protracted, hot dry season, most trees lose their leaves, with the exception of those that are found around rivers. The majority of their species are pollinated by animals, and many of them flower while they are without leaves. The hot, wet season is when biological activity is at its peak.

Because they are less nutrient-leached than the soils of wetter regions, the soils of the tropical deciduous biome are some of the best soils in the tropics for agriculture. Due to this, the majority of tropical deciduous woods have been destroyed to make room for farming and cattle grazing. In various continents, restoration activities are in progress.

Tropical Evergreen Woods Have a Join With Upper Line

In equatorial places where annual total precipitation surpasses 250 cm and the dry season does not last more than two or three months, tropical evergreen forests can be found. They have the highest diversity of plant and animal species of any biome, with up to 500 different tree species found in every square kilometre. Tropical evergreen forests have the highest total productivity of all biological communities in addition to having an enormous diversity of species.

The majority of mineral nutrients are, however, bound by the flora. Normally, soils cannot support agriculture without extensive fertiliser applications. Tropical mountain slopes have shorter trees than tropical lowlands do. There are more epiphytes (plants that grow on other plants and get their nutrients and hydration from the air and water instead of soil) and their leaves are smaller.

The study of island biogeography examines patterns in species distribution on islands as influenced by ecological and evolutionary processes connected to island characteristics like isolation and area. According to the MacArthur-Wilson hypothesis of island biogeography, the species diversity of an island's biota is determined by two processes, immigration and extinction. The immigration rate declines and the extinction rate rises as the number of species on the island rises. While the extinction rate falls with island area, the immigration rate decreases with isolation (distance effect) (area effect). A balance

between species diversity and immigration and extinction rates is reached. Species turnover occurs when an island goes extinct and is replaced by the arrival of new species. One of the ideas that have had the most influence on contemporary biogeography, ecology, and evolutionary biology is the equilibrium theory of island biogeography. Additionally, it has had a significant impact on conservation biology, especially with efforts to create a theoretical framework for the creation of nature reserves. The equilibrium theory of island biogeography should not be blindly applied to nature conservation, as several components of the theory are still unproven.

A Theory of Island Biogeography's Equilibrium

Species–Area Relationship

It has long been known that there is a monotonic increase in the number of species with increasing island area (or sampling area of terrestrial communities). In many instances, a power function with the following shape has been demonstrated to best suit observations among the different mathematical representations for the species-area relationship:

S = log or cAz (1) S = zlog; S is species diversity (the number of species, also known as species richness), A is area, and c and z are positive constants where S is the number of species. Z has a theoretical value of 0.263 and typically varies between 0.18 and 0.35, while c typically indicates the impact of geographic variation on species diversity. The usual method for estimating values for these constants is linear regression.

Although the aforementioned equation has been used frequently, it has limited ability to explain or predict. As a result, three hypotheses have been put forth to explain the species-area relationship: Williams' (1964) habitat diversity hypothesis; Connor and McCoy's (1979) passive sampling hypothesis; and Munroe's (1948, 1953), Preston's (1962), and MacArthur and Wilson's (1948, 1962) dynamic equilibrium hypothesis (1963, 1967). The species-area link, according to the habitat diversity hypothesis is the outcome of a positive correlation between area and habitat diversity as well as between habitat diversity and species diversity. The passive sampling hypothesis simply views isolated taxonomic groups as samples or subsets of broader populations. Therefore, sample size and intensity both affect species diversity; Coleman, et al., (1982) offered a related theory known as the random placement hypothesis that goes along these lines. The article's focus, the dynamic equilibrium hypothesis, has had the most impact on island biogeography and ecology.

Area impacts the observation that as island acreage grows, species extinction rates decrease.

Effect of distance the observation that as an island is further from its continental source of colonising species, the rate of species immigration declines.

Evolutionary curve is the line connecting the number of species already existing on an island to the rate of species extinction. Migration rate is the line connecting the pace of species immigration to the total number of species on an island.

Biogeography of islands

The examination of patterns in species distribution on islands as influenced by ecological and evolutionary processes connected to island features such locality and isolation. When conspecific immigrants arrive, existing populations receive demographic support and their genetic diversity is increased, which reduces the rate of species extinction.

Curve of species-area is the line connecting species diversity to island size. Animal variety includes either the total amount of the number of species (species richness) or includes both the species count and relative abundance of them. The biosphere, or the web of life that resides in and is dependent upon the inorganic spheres, is an essential component of man's ability to live a long, healthy life and necessary for the existence and functional state of human species.

Our life is made feasible and delightful by the diversity of living things that makes the biological world. Walter and Rosen (1985)

first used the term biodiversity, which is the shorthand for 'biological diversity'. Nearly four billion years ago, life first appeared on Earth, and it took nature more than a billion years to create the vast and intricate variety of life that exists today. According to scientists, there are between 10 and 80 million different species on the planet (Wilson, 1988), of which 1.4 million have been officially recorded. However, we are rapidly losing this history that dates back millions of years. The entire living world will undoubtedly suffer serious effects from the decline in life's species diversity. Studying the many types of life on Earth and the factors that contribute to their extinction has become of utmost importance.

The overall variety of life on our planet is known as biodiversity. Biodiversity is the sum of all the different types of bacteria, plants, and animals that are present in a system, including their numerous races, variations, and species. The term 'biodiversity' is currently used often by a wide range of people, including the general public, environmental organisations, environmentalists, businesspeople, and economists. Therefore, it is crucial to understand the definition of biodiversity, which is acknowledged as a distinct science with its own guiding principles.

The following are some key definitions of biodiversity.

1. Biodiversity is the diversity of life in all of its manifestations, scales, and configurations. Species diversity, genetic diversity, and environmental diversity are all included [International Union for Conservation of Nature and Natural Resources-(lUCN)].
2. Biodiversity was defined as "the variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are a part" during the Rio de Janeiro Earth Summit. This covers diversity of ecosystems, between species, and within species.
3. According to the US Congressional Bio-diversity Act, biological diversity includes ecosystem diversity, species diversity, and genetic diversity. It is the variety and variability among living creatures and the ecological complexity in which they occur.
4. In its most basic form, biological diversity can be defined as the variety of life and its processes. This encompasses the genetic diversity of living things, as well as the groups and ecosystems in which they coexist. We shall discuss several important facets of biodiversity and its preservation in this essay.

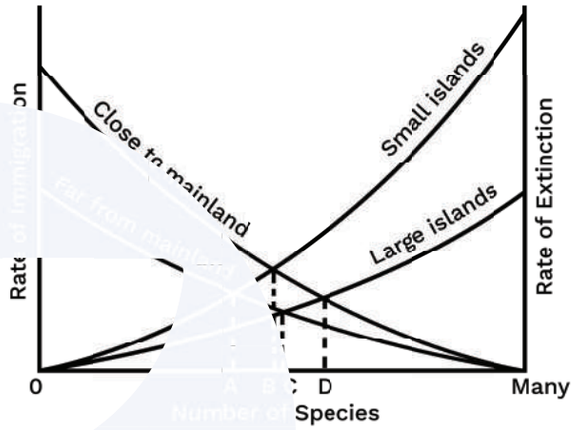

Fig. 10.26 Island Biogeography

Biodiversity Types

Three different levels of biodiversity are typically studied: species variety, genetic diversity, and ecosystem diversity.

1. **Species diversity:** The diversity of habitats on Earth likely made it possible for species to evolve. It alludes to the variety of species found in a given area. The number of species present in an area could be used to quantify this diversity. Species diversity and biodiversity are often used interchangeably. In actuality, it alludes to species richness, or the number of species present in a given area or environment. The total number of species across all taxonomic categories is a common way to measure global diversity. As was previously indicated, an estimated 1.4 million species have so far been discovered. Again, there are three levels of study of species diversity: Beta diversity (change

in species complement between patches), gamma diversity (number of species coexisting at a place), and alpha diversity (number of species in a large area, e.g., a country). This series can also be expanded to include omega diversity for the entire biosphere and delta diversity for certain biomes.

Some writers refer to it as taxon diversity (variety of taxa within a community of an area). It is known as species diversity because it is often researched at the species level. The word taxon diversity is more applicable when considering the taxonomic levels such as genus and family.

2. **Genetic diversity:** There are several subspecies, varieties (which are distinguishable morphological variations within a species), forms (which are typically used to recognise and describe sporadic variations in a single morphological feature), or strains that are marginally different from one another within a species.

These variances result from small variations in the way their genes are organised. Genetic diversity refers to the variety in a species' genetic composition. A species is said to be rich and diversified in its genetic organisation if it has a high number of variants or strains. Genetic or chromosomal mutations cause genetic changes in members of a species. A crucial component of biodiversity, genetic variation among populations is seen as a 'prerequisite or adaptation and evolutionary change'. Alleles, or genes sharing the same locus on a chromosome are frequently used to express genetic diversity and are mostly examined at the population level. Different modern methods, including DNA fingerprinting, polymerase chain reaction, restriction site mapping, and DNA sequencing can measure genetic variants.